Granger Drain Fecal Coliform Bacteria Total Maximum Daily Load Assessment and Evaluation

Final

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Water Quality Program

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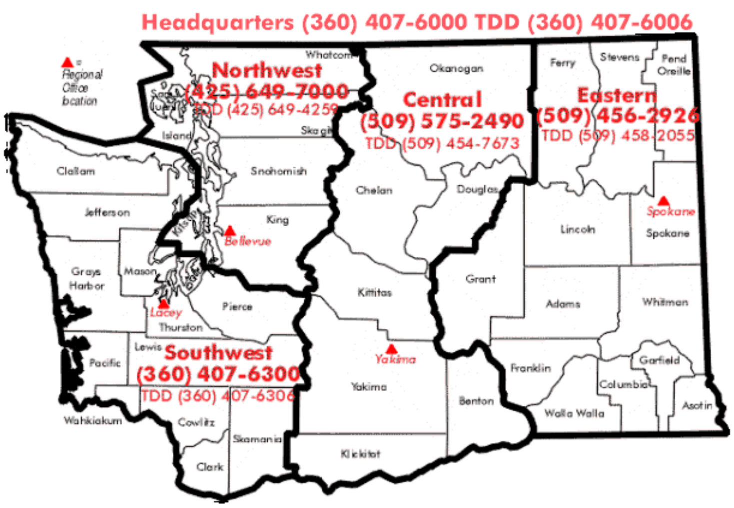

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Abstract

Section 303(d) of the federal Clean Water Act requires states to identify water bodies where technology-based controls have been insufficient to meet applicable water State of Washington's (State's) 1998 303(d) listing due to exceedances of the State's water quality standards for fecal coliform (FC) bacteria, dissolved oxygen, temperature, ammonia, pH, and various persistent pesticides. As a result, the Washington State Department of Ecology (Ecology) is required to conduct a FC total maximum daily load (TMDL) assessment/evaluation of the Granger Drain watershed. The principal source of the FC pollution has historically been attributed to the manure produced by the numerous animal feeding operations (AFOs) located throughout the watershed. Other potential sources such as "hobby farms", wildlife, septic tanks (sub-basin #1&2) and urban runoff have been considered to be minor FC contributors.

In 1992, FC pollution in the Granger Drain watershed was strongly and positively correlated to the amount and location of *dairy/feedlot acreage*, *corn/wheat acreage* and *rill irrigation acreage*, but negatively correlated to *alfalfa/pasture acreage* and *sprinkler irrigation acreage*. In 1995, only dairy-related land-use parameters were available for analysis with the quantity of cows indicating a positive correlation to FC densities. Later data from 1998 and 2000 determined that no on-site dairy-related parameters were significantly correlated with FC pollution. The trend of FC pollution away from on-site dairy parameters in the watershed's surface waters reflects positively upon that industry's improvements in manure management. Another agricultural land-use survey conducted in 1999, indicated that in 1999 and 2000 there was found a positive correlation between FC densities and *row crop acreage*. This assessment/evaluation hypothesizes that overland runoff from manured irrigated agriculture, especially rill irrigation, is a principal transport method and source of FC pollution reaching the mainstem Granger Drain. Similarly, Gburek, W.J. (2000) stated that: "Surface runoff, [is] the primary vehicle for…pathogen transport…" Additionally, subsurface drainage in the Granger Drain watershed has been identified as another transport mechanism of substantial FC pollution.

In support of the overland runoff hypothesis, there was observed a highly significant but moderate correlation between FC pollution and suspended sediment (AKA: TSS) found in the mainstem Granger Drain. Additionally, from 1997-2000 the TSS concentrations in the Granger Drain decreased by 85% while FC densities have decreased by 67%. Such reductions are presumed to be the combined result of the implementation of nutrient (manure) management plans by various dairies, and various best management practices (BMPs) for mitigating suspended sediment in runoff from irrigated agriculture, including: polyacrylamide and conversion from rill to sprinkler/drip irrigation. The *Granger Drain Fecal Coliform TMDL* will require that all points in the mainstem Granger Drain, as well as all points in the SVID and RID irrigation water supply canals, comply with a 90th percentile interim target of 510 colony forming units (cfu)/100 mL commencing with the 2007 irrigation season. Finally, the TMDL will require that those compliance points comply with both tiers of the State's Class A FC standards commencing with the 2012 irrigation season. The 1992-2000 monitoring data suggests that such compliance can reasonably be met through continued implementation of prior types of BMPs to control suspended sediment. Other BMPs will be investigated and may need to be implemented.

Acknowledgments

The completion of the *Granger Drain Fecal Coliform Bacteria TMDL Assessment and Evaluation* would not have been possible without the help of the following people and agencies.

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- *All of the other active members of the Technical Advisory Workgroup*[1]*:*
    - *Stuart Crane*, Yakima Nation
    - *Laurie Crowe*, South Yakima Conservation District
    - *Sandra Embrey*, USGS
    - *Steve George*, Hop Growers of Washington
    - *Walt George*, South Yakima Conservation District
    - *Jay Gordon*, Washington State Dairy Federation
    - *Julia Hart*, Daily Sun News
    - *Jim Lapinski*, Yakima Valley Conference of Governments & Town of Granger
    - *Marie Lilga*, Washington State University - Prosser
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[1] The Technical Advisory Workgroup membership consists of individuals that were deemed by Ecology to have a vital role in the development and accuracy of the *Granger Drain Fecal Coliform Bacteria TMDL Assessment and Evaluation*. The workgroup offered extensive comments on all of the early drafts of this assessment/evaluation, the majority of which were integrated into the final draft. However, the process was not based on a 100% consensus approach and it was not necessary for all members to agree with everything in the final draft document, although they did agree that the water quality in the Granger Drain needs improvement. All specific written disagreements by individual workgroup members with the final draft are included in the Responsiveness Summary section of the final TMDL submittal document.

Executive Summary

The lower Yakima River and the mainstem Granger Drain have not met the Class A fecal coliform (FC) water quality standard of the State of Washington (State) for over three decades of monitoring. The Washington State Department of Ecology (Ecology) and other agencies have historically attributed the excessive FC contamination to the numerous animal feeding operations (AFOs) within the watershed. However, there are present other potential sources of FC pollution such as: "hobby farms", septic tanks, wildlife and urban runoff. FC pollution is extremely seasonal throughout the watershed with the greatest bacterial densities always occurring during the irrigation season of the local agriculture.

Since the 1970's, the lower Yakima River has been sampled by various governmental (local, State and federal) entities for documenting the amount of pollution corresponding to FC and other pollutants. Those studies have consistently found FC densities far in excess of State standards in the Yakima River just downstream from the mainstem Granger Drain outfall; while background conditions (without agriculture) have typically been less than 25 cfu/100 mL. This assessment/evaluation's analysis of more recent monitoring data has suggested that FC pollution in the Granger Drain watershed is still related, either directly or indirectly, to the numerous livestock within the area. Specifically, FC pollution in the watershed during 1992 was positively correlated *dairy/feedlot acreage*, *corn/wheat acreage* and *rill irrigation acreage*. In 1995, although no crop land-use categories were available, the worst cases of FC pollution were correlated to the *# cows* on-site at dairies. Later (1998 and 2000) monitoring data showed that dairy-related parameters were not significantly correlated with FC pollution, which positively reflects upon that industry's implementation of improved on-site manure management activities and the *1998 Washington Dairy Nutrient Management Act* requirements. However, the monitoring data also determined that *row crop acreage* correlated well to FC densities, which suggests that irrigated agriculture is still a predominant source of FC pollution in the watershed.

Irrigation-induced overland runoff from agricultural fields is hypothesized by this assessment/evaluation to be a principal transport mechanism of FC pollution to reach the watershed's surface waters. To support the hypothesis, an in-depth analysis of the 1997-2000 data showed a highly significant and moderate correlation between FC pollution and TSS in the mainstem Granger Drain. This is a result of the fact that FC has a strong affinity to adsorb onto very small particles of suspended sediment and travel substantial distances in the water column.

In addition to overland runoff, the Granger Drain watershed has substantial subsurface drainage, which has been shown to transport FC pollution. The South Yakima Conservation District (SYCD) stipulated in its 1992 report that there are more miles of subsurface drainage than surface drainage in the watershed: 26.9 and 13.8 miles, respectively. Although such drainage is described as being 8 to 10 feet deep, it still transports significant amounts of FC pollution in densities equivalent to surface drainage systems. A later (year-2000) United States Geological Survey (USGS) synoptic sampling identified that the greatest FC densities (up to 460,000 cfu/100 mL) collected during both the irrigation and non-irrigation seasons were sampled from subsurface drainage systems throughout the Yakima River Basin. FC bacterial access to these drainage systems had been presumed difficult; however, historical records indicate that at least one of the watershed's dairies was found discharging wastewater into a nearby subsurface drain.

From 1992 through 2000, the geometric mean and 90th percentile FC densities within the mainstem Granger Drain were reduced approximately 91% and 99%, respectively. The decrease in FC densities are presumed to be the result of a long history of successful watershed pollution abatement through improved manure management (voluntary and required) at many dairies, and implementation of BMPs dedicated to reducing the amount of suspended sediment contained in runoff from irrigated agriculture. Such present BMPs include, but are not limited to: PAM (polyacrylamide), sedimentation basins, and conversion from rill to sprinkler and drip irrigation.

Based on the 2000 data, an additional 87% reduction of FC pollution will be required before the mainstem Granger Drain can comply with the State's two-tiered Class A FC water quality standard (geometric mean of 100 cfu/100 mL and 90th percentile of 200 cfu/100 mL). The *Granger Drain Fecal Coliform Bacteria TMDL* is designed to allow the ultimate compliance with that standard by means of a stepped approach based on reasonable assurance. The TMDL will require that all points in the mainstem Granger Drain, as well as all points in the Sunnyside Valley Irrigation District (SVID) and Roza Irrigation District (RID) irrigation water supply canals, comply with an interim FC 90th percentile target of 510 cfu/100 mL and, finally, the State's Class A FC standard. Data projection analysis associated with this assessment/evaluation indicates that ultimate compliance with the State's Class A FC standard is reasonably assured through strict adherence to the requirements of Ecology's *Lower Yakima River Suspended Sediment TMDL* and the *1998 Washington Dairy Nutrient Management Act*. Therefore, new types of BMPs beyond those already being implemented may not be necessary for meeting the FC targets and timeframe set forth in the *Granger Drain Fecal Coliform Bacteria TMDL*. However, future FC monitoring data will be evaluated every two years in order to maintain continual reasonable assurance that FC mitigation is proceeding adequately. It is important to understand that such evaluations could possibly indicate, at any time, that new types of BMPs would need to be implemented. Continued cooperation of both the private and public sectors will be essential for the complete success of the *Granger Drain Fecal Coliform Bacteria TMDL* in bringing the watershed's FC bacterial densities into compliance with Class A standards.

According to this assessment/evaluation, future work in the Granger Drain watershed shall include:

1. Continuation of monitoring FC pollution all in the mainstem Granger Drain, with selection of an additional site downstream of the town of Granger;

2. Identification and mapping of all subsurface drainage system outfalls, with commencement of monitoring of outfalls to the mainstem Granger Drain;

3. Completion all requirements of Ecology's *Lower Yakima River Suspended Sediment TMDL* and the *1998 Washington Dairy Nutrient Management Act*;

4. Implementation of BMPs directed at FC pollution from pastures, AFOs and "hobby farms", such as: stream-bank fencing, off-stream watering and grass buffer zones;

5. Implementation, as needed, of additional BMPs (including in sub-basin #9);

6. Evaluating every two years the latest FC monitoring data to assure compliance with the *Granger Drain Fecal Coliform Bacteria TMDL* goals; and

7. Conducting various experiments to determine major FC pollution sources.

Introduction

Description of Area

The lower Yakima River Basin covers approximately 2,950 square miles and is one of the most intensively irrigated and agriculturally diverse areas in the United States. Agricultural irrigation return flows account for as much as 80 to 90% of the mainstem river flow in the lower Yakima River (USGS, 1999), which can significantly influence the water quality in the area. Many of these return flows, such as the Granger Drain, contain agricultural-related pollution, including fecal coliform (FC) bacteria.

The Granger Drain watershed is comprised of approximately 48 square miles located in the lower reach of the Yakima River Basin (Figure 1). The mainstem Granger Drain receives water from a major agricultural watershed containing a vast network of both surface and subsurface drainage systems: 13.8 miles and 26.9 miles, respectively (SYCD, 1992).

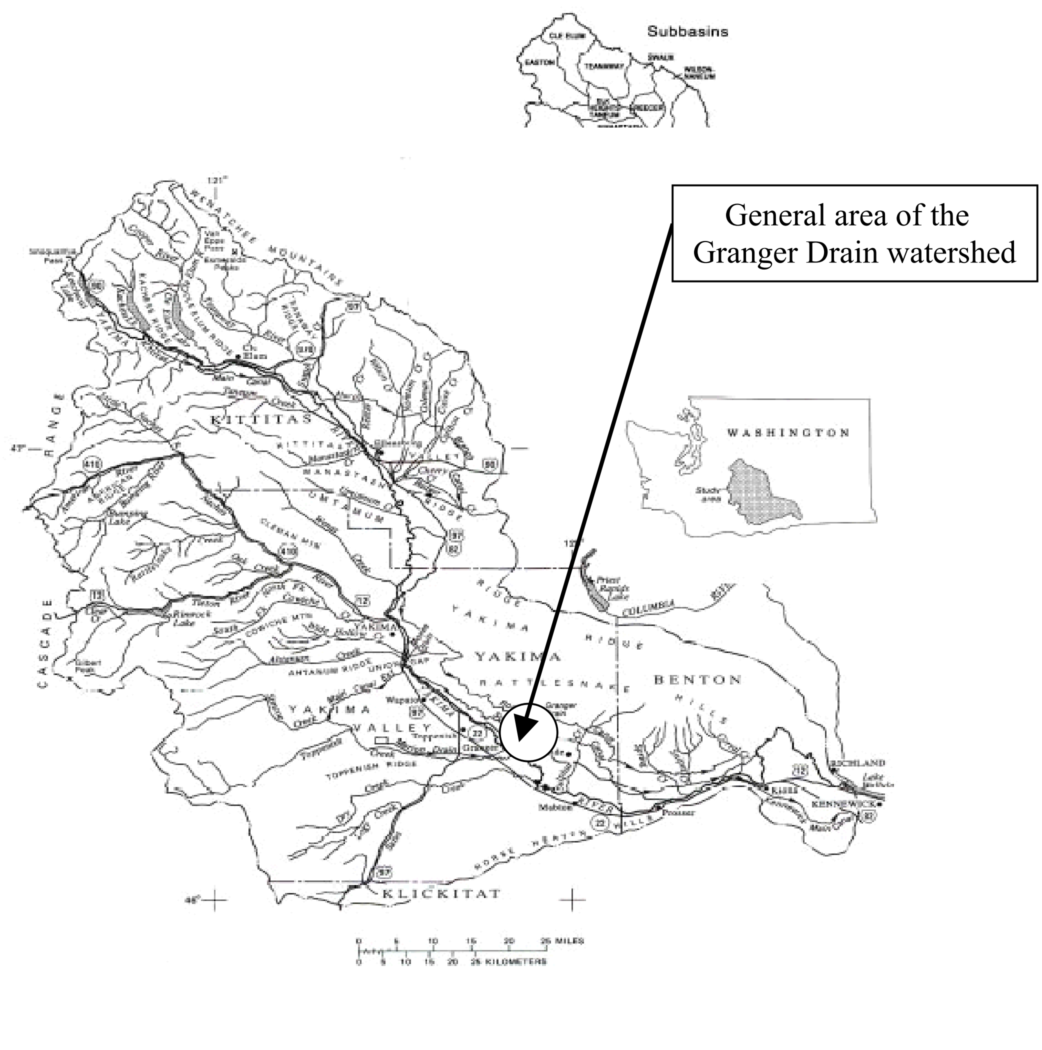

Figure 1: Yakima River Basin

Figures 2 and 3 illustrat… erspectives. It should be noted that an … which comprises approximately 2,000 ac… rain and Interstate 82, but which still contr…

The climate of the watershed is considered semi-arid, with an average annual rainfall of only 7 to 9 inches that occurs principally during the months of November through March. The prime growing season is 180 – 210 days long and typically occurs from April through October, throughout which the crops conservatively receive an average of 36 inches of irrigation water, although more can be delivered depending on availability. The soils in the area are predominantly silt-loam in texture (Warden silt-loam) with variable depths, low in organic matter and have an average porosity.

Hydrology

The mainstem Granger Drain (new segment ID# = EB21AR, old segment ID# = WA-37-1024) is located within the Water Resource Inventory Area (WRIA) 37 at Stream Route 135.707 within Township 10N, Range 21E. It is also one of three major irrigation return flows discharging into the Yakima River (River Mile 82.8) below the Sunnyside Valley Irrigation District (SVID) dam diversion.

The mainstem Granger Drain, for purposes of the *Granger Drain Fecal Coliform Bacteria TMDL*, is defined as the principal irrigation return collector drain that runs parallel to Interstate-82 and begins immediately south of the community of Outlook and extends westward to the town of Granger. The mainstem drain then turns southwest, passes through the town, and finally discharges into the Yakima River on the immediate north side of the boat ramp, which is located just to the northwest of the town's large recreational pond near the municipal wastewater treatment plant. According to State regulations (Chapter 173-201A WAC), the mainstem Granger Drain is classified as a "Class A" waterbody. Table 1 lists the State's Class A water quality standards.

During the peak growing season (April through October), crops in the Granger Drain watershed are highly dependent on irrigation water diverted from the Yakima River and supplied by the SVID, Roza Irrigation District (RID) and Outlook (pumped from the SVID canal) irrigation water supply canals. Originally, the predominant irrigation method for row crops was rill, or furrow, surface irrigation type, while drip and sprinkler irrigation have typically been used for permanent crops such as orchards and vineyards. Rill irrigation has historically caused excessive amounts of pollutants (e.g., suspended solids, pesticides) to run off the surface of fields, flow into the mainstem Granger Drain and then into the Yakima River.

Since 1978, significant efforts have been made by the Natural Resources Conservation Service (NRCS), Washington State University Cooperative Extension (WSUCE), Washington State Department of Ecology (Ecology), Farm Service Agency (FSA), South Yakima Conservation Districts (SYCD), and the Roza-Sunnyside Board of Joint Control (RSBOJC) to implement best management practices (BMPs) throughout the watershed for purposes of specifically reducing surface runoff, TSS, turbidity and DDT (and its metabolites).

Figure 2: Granger Drain Watershed

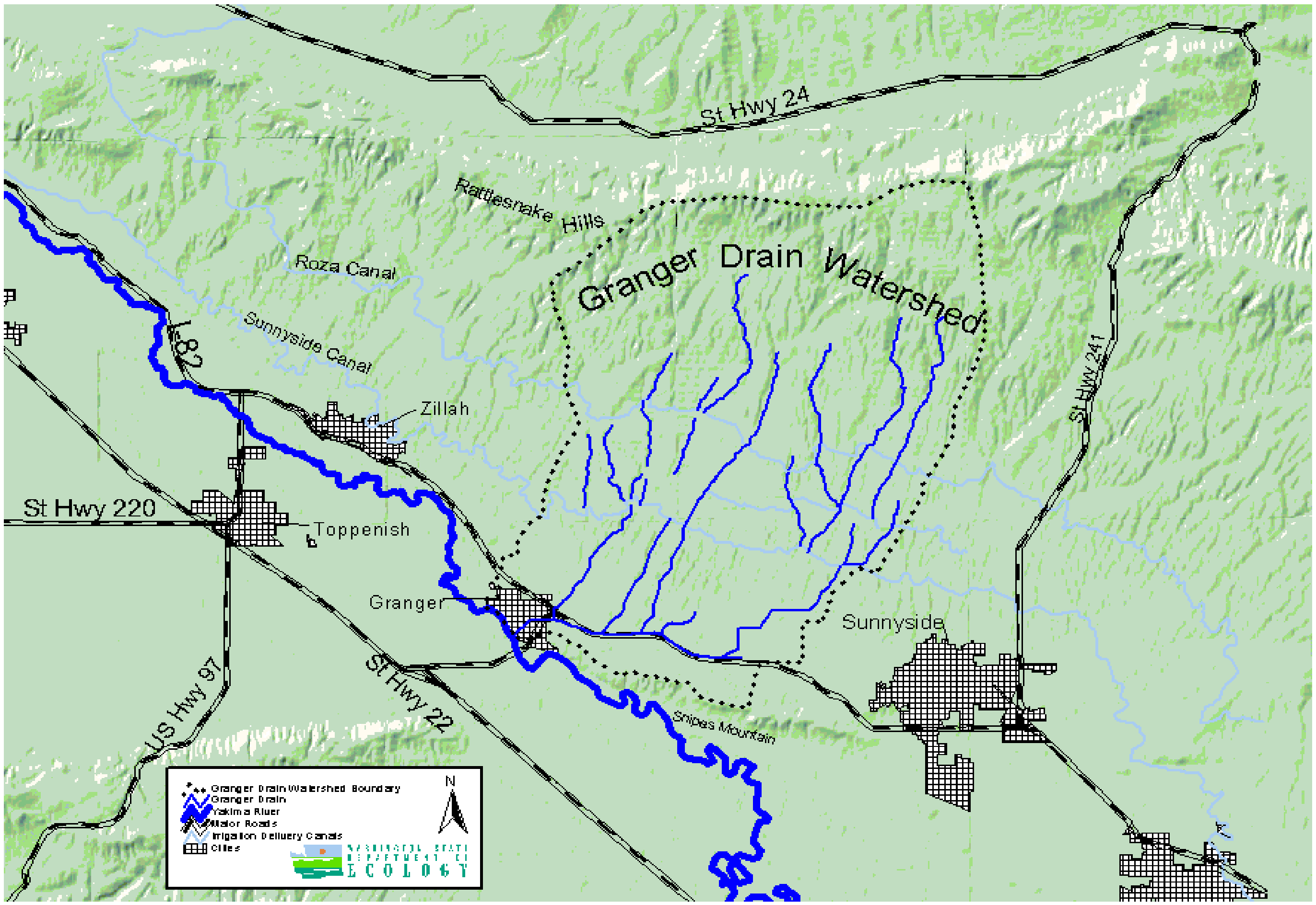

Figure 3: Granger Drain Watershed Sub-basins

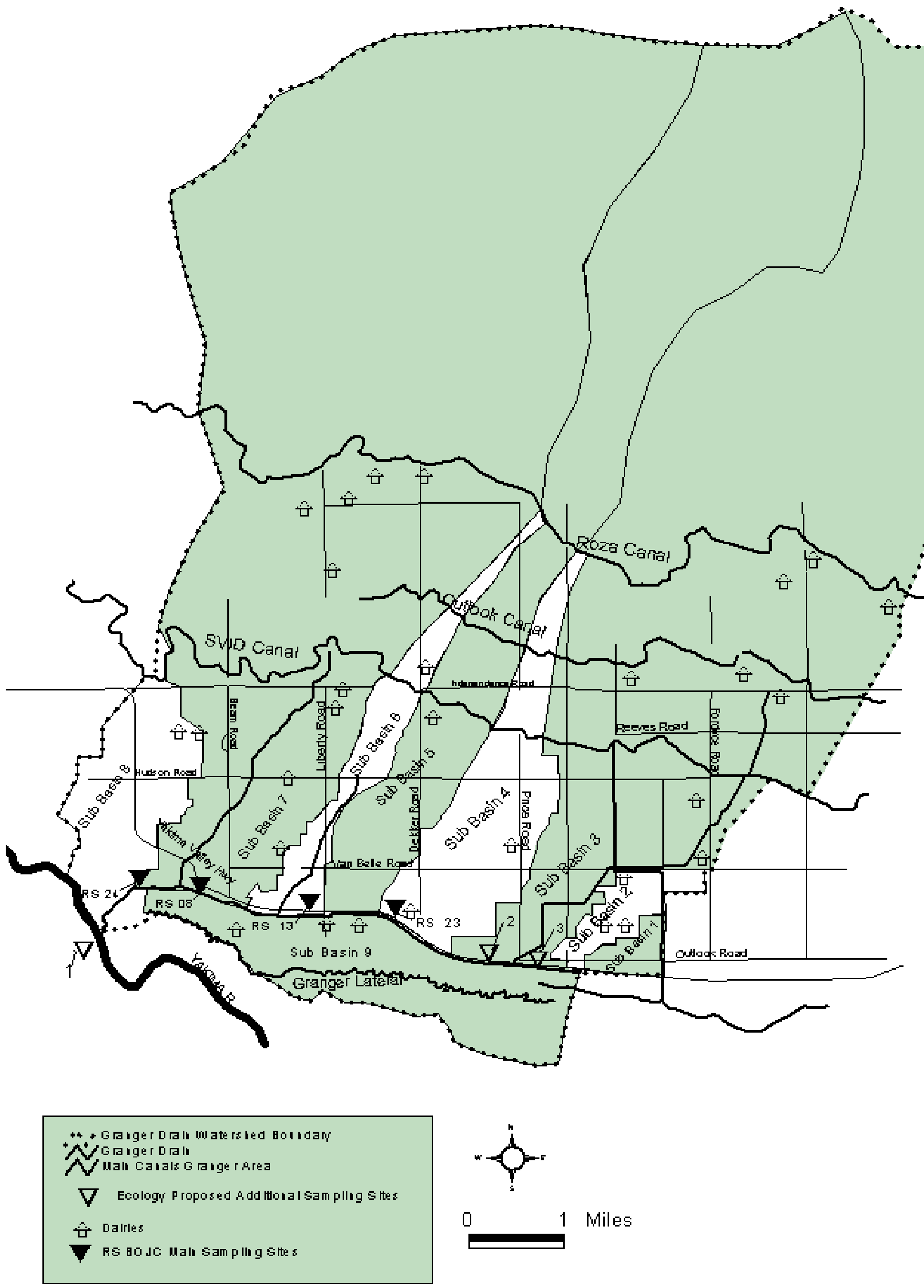

Table 1: Class A Water Quality Standards (freshwater)

General:	Water of this class shall meet or exceed the requirements for all or substantially all uses.
Characteristic Uses:	Shall include, but not be limited to, the following: water supply (domestic, industrial, agricultural); stock watering; salmonid migration, rearing, spawning, and harvesting; wildlife habitat; recreation (primary contact recreation, sport fishing, boating, and aesthetic enjoyment); commerce and navigation.
Fecal Coliform:	Shall both not exceed a geometric mean value of 100 cfu/100 mL and not have more than 10% of all samples obtained for calculating the geometric mean value exceeding 200 cfu/100 mL.
Dissolved Oxygen:	Shall exceed 8.0 mg/L.
Total Dissolved Gas:	Shall not exceed 110% of saturation at any point of sample collection.
Temperature:	Shall not exceed 18ºC due to human activities. When natural conditions exceed 18ºC, no temperature increase will be allowed which will raise the receiving water temperature by greater than 0.3ºC; nor shall such temperature increases, at any time, exceed t=34/(T+9). ("T" represents the background temperature as measured at a point or points unaffected by the discharge and representative of the highest ambient water temperature in the vicinity of the discharge. "t" represents the maximum permissible temperature increase measured at a mixing zone boundary.)
pH:	Shall be within the range of 6.5 to 8.5 with a human–caused variation within the above range of less than 0.5 units.
Turbidity:	Shall not exceed 5 NTU over background turbidity when the background turbidity is 50 NTU or less, or have more than a 10% increase in turbidity when the background turbidity is more then 50 NTU.
Toxic, radioactive, or deleterious material:	Shall be below those which have the potential either singularly or cumulatively to adversely affect characteristic water uses, cause acute or chronic conditions to the most sensitive biota dependent upon the those waters, or adversely affect public health, as determined by Ecology.
Aesthetic Values:	Shall not be impaired by the presence of materials or their effects, excluding those of natural origin, which offend the senses of sight, smell, touch, or taste.

Problem Statement

The mainstem Granger Drain has been placed on the State's 1998 303(d) list of impaired waterbodies due to the following parameters exceeding the State's Class A water quality standards (Table 1): ammonia-N, DDD, DDE, DDT, dieldrin, DO, endosulfan, FC, pH and temperature. Historically, Ecology and other water quality monitoring agencies have attributed the FC pollution within the Granger Drain watershed to the manure produced by the area's numerous of livestock and concentrations of animal feeding operations[2] (AFOs), which includes various dairies. Additionally, the WSUCE (1998) stated that: "Dairy manure is added to much of the Granger Drain [watershed]…[which] results in an easy disposal system for dairy manure and relatively low priced fertilizer for row crops." The over-abundance of manure can, however, create pollution problems. In fact, the United States Department of Agriculture, Natural Resource Conservation Service (1995) stated that determined that as animal enterprises are concentrated: "Land for manure application at agronomic rates is often not available without prohibitive transportation costs, and the tendency to *dispose* of the manure (as opposed to using its nutrients) increases." Due to the concentration of dairy cows, as well as other livestock within the Granger Drain watershed, the FC pollution problem in the area has probably been the result of inappropriate on-site manure management and off-site manure application.

Over the past several years, efforts by the RSBOJC, SYCD, NRCS, FSA, WSUCE and Ecology to minimize contamination from these sources have had significant success. However, the mainstem Granger Drain's listing of *impaired* indicates that past implementation of pollution control methods have not been effective in enabling that waterbody to comply with the State's water quality standards. More restrictive point and non-point source controls are now required. Public attention on chronically poor manure management practices at some of the larger concentrated animal feeding operations[3] (CAFOs) within the Granger Drain watershed has occurred in recent years through highly-publicized third-party lawsuits. This assessment/evaluation will endeavor to direct BMP implementation so that the mainstem Granger Drain will comply with the State's two-tiered FC Class A water quality standard commencing with the 2012 irrigation season. Continued non-compliance with such standard would pose a health hazard to those who have incidental contact with the water contained in the mainstem Granger Drain. The loss of any beneficial uses requires that the mainstem Granger Drain be listed as *impaired* and that a total maximum daily load (TMDL) analysis be conducted. TMDLs are defined in 40 CFR Part 130 as the determination of maximum allowable individual point source wasteload allocations and non-point source load allocations.

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2 An animal feeding operation (AFO) is defined as: A commercial lot or facility where animals have been, are, or will be stabled, or confined and fed or maintained for a total of 45 days or more in any 12-month period. The animal stable or confinement area cannot sustain crops, vegetation, forage growth, or post-harvest residues in the normal growing season. It is not necessary that the same animals are fed or maintained on the lot for the 45-day period nor do the 45 days need to be consecutive.

3 A confined animal feeding operation (CAFO) is defined as: An AFO which discharges at any time other than during only a 25-year, 24-hour or greater storm event. For example: an AFO which discharges during a chronic or catastrophic rainfall event that does not exceed the 25-year 24-hour precipitation amount (1.6 inches for the Granger Drain watershed) automatically triggers the classification as a CAFO and an NPDES permit is required.

FC was chosen as the parameter of concern for this assessment/evaluation because BMPs used for reducing FC concentrations within the Granger Drain have an excellent potential to mitigate other 303(d)-listed contaminants such as dissolved oxygen (DO), pH, and ammonia. In fact, BMP implementation throughout the watershed during the years 1997-2000 has also resulted in the following water quality improvements: a 66% decrease in FC densities in the mainstem Granger Drain; a 10% increase in DO; and a 76% decrease in Total Kjeldahl Nitrogen. Past BMP implementation has been the result of the previous *Lower Yakima River Suspended Sediment TMDL* (LYRSS TMDL), which applies to all points within all tributaries and drains of the Lower Yakima River, which includes the mainstem Granger Drain. Thus, the *Granger Drain Fecal Coliform Bacteria TMDL* is actually the second TMDL to apply to the mainstem Granger Drain. The cascading positive effect on other 303(d) pollutant parameters suggests that an orderly succession of TMDLs (1st = Suspended Solids, 2nd =FC bacteria, etc.) for the mainstem Granger Drain will eventually allow that waterbody to regain compliance with all of the State's Class A water quality standards.

Objectives

The main objectives of this assessment/evaluation are to:

1. Review historical monitoring data to:

   A. Illustrate the FC water quality impact of past and present land use activities;

   B. Assess the effectiveness of past implementation of BMPs; and

   C. Establish how divergent is the mainstem Granger Drain from meeting the State's two-tiered FC water quality standard: geometric mean concentration of 100 cfu/100 mL, and not more than 10% of the samples exceeding 200 cfu/100 mL. (The parameter of a 90th percentile[4] will be utilized by the *Granger Drain Fecal Coliform Bacteria TMDL* as a surrogate for checking compliance with the last tier of the above FC water quality standard);

2. Establish FC TMDL targets and timelines for the Granger Drain watershed in order to guide future point source and non-point source pollution monitoring and control programs inside the watershed; and

3. Set wasteload and load allocations for FC bacteria for point and non-point sources located within the Granger Drain watershed.

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[4] A 90th percentile, for compliance with the *Granger Drain Fecal Coliform Bacteria TMDL*, shall be interpreted as the single data point that represents the beginning of the highest ten percent (10%) of data points after ranking all applicable data points, from highest to lowest. For example: if a sample contains 1 to 19 data points, the 90th percentile shall be the data point with the highest value; if a sample contains 20 to 29 data points, the 90th percentile shall be the data

point with the second highest value; if a sample contains 30 to 39 data points, the 90th percentile shall be the data point with the third highest value.

Background

Significance of Fecal Coliform Bacteria Pollution

There are more than 100 different waterborne enteric pathogens known to be related to the feces of warm-blooded animals. Many diseases/organisms can be transmitted to humans from animal manure including: anthrax, salmonella, tetanus, tuberculosis, cryptosporidium, giardiasis and *Escherichia coli* (*E. coli*) O157:H7. (However, not all *E. coli* are 0157:H7).

Due to the diversity and unpredictability of individual pathogens, water quality testing for each individual pathogen would be very time-consuming, technically intensive, and prohibitively costly. Fortunately, testing for a fecal contamination indicator organism is much easier and has been utilized during the past 100 years. The indicator organism, FC, is currently the standard for determining microbial water quality in the State, even though the USEPA has endorsed, and Ecology is in the process of changing to an *Enterococci*-based water quality standard.

Table 2 shows the comparative daily output of FC bacteria in the manure of individuals of various animal species. It is important to note that dairy and beef cows have the highest bacterial output of all the species tested.

Table 2: Daily Output of FC Bacteria in Animal Manure

Animal Type	FC Output/Individual (cfu/100 mL)
beef cow[1] (confined)	1.04×10^{11}
dairy cow[1] (confined)	1.01×10^{11}
goose[4]	4.90×10^{10}
beef cow[2] (grazing)	3.84×10^{10}
sheep[1]	1.20×10^{10}
hog[1]	1.08×10^{10}
dog or cat[6]	5.00×10^{9}
duck[1]	2.43×10^{9}
elk[2]	2.06×10^{9}
human[5]	2.00×10^{9}
dog[7]	9.90×10^{8}
deer[3]	5.00×10^{8}
horse[1]	4.20×10^{8}
chicken[1]	1.36×10^{8}
turkey[1]	9.30×10^{7}
beaver[7]	9.30×10^{7}
cat[7]	5.04×10^{6}

[1] From ASAE D384.1 DEC99: Manure Production and Characteristics.
[2] From the Oregon Department of Environmental Quality.
[3] From North Carolina State University.
[4] From LIRPB, 1978.

[5] From Metcalf and Eddy, 1991.
[6] From Horsley and Witten, 1996.
[7] From the Virginia Department of Environmental Quality.

The presence of FC indicator organisms in a water sample does not necessarily mean that pathogenic organisms are present. However, excessive amounts of FC in a waterbody does represent a statistically significant health risk for human beings and will typically result in the loss of the primary and secondary beneficial uses in that waterbody (swimming, fishing, boating, incidental contact and water sports) and in the receiving waters. Such beneficial uses are required to be protected by both the federal CWA and the State's own surface water quality standards.

Land-use Inventory

The major agricultural land-use activities within the Granger Drain watershed are irrigated agriculture, pastures and AFOs (specifically dairies). In addition, the watershed had an 83% increase in the number of dairy animals from 1989 to 2000 (20,000 to 36,500). In 1992, the principal agricultural crops within the individual watershed's sub-basins are detailed below in Table 3. The principal irrigation methods are detailed below in Table 4. *Dairy/feedlot acreage* in Table 3 is defined as only the confinement area of animals and does not include any pasture or manure application acreage. The *No irrigation acreage* category in Table 4 includes both cattle confinement areas and low lying pastureland.

Table 3: 1992 Crop Inventory (SYCD, 1992)

Sub-basin #	Corn/ Wheat Acres	Orchard/ Grape Acres	Dairy/ Feedlot Acres	Alfalfa/ Pasture Acres	Asparagus/ Hops/ Mint Acres	Flowers/ Berries/ Melon Acres	Total Crop Acres	Idle Acres	Total Agricultural Acres
1&2	94.5	0	89	75.5	261	0	520	110	630
3	573	89	106	267	710	146	1,891	40	1,931
4	283	192	52	357	568	38	1,490	64	1,554
5	257	132	38	498	199	0	1,124	14	1,138
6	66	186	0	276	155	0	683	48	731
7	385	465	91	1,203	381	37	2,562	206	2,768
8	190	162	50	305	272	0	979	14	993

Table 4: 1992 Irrigation Inventory (SYCD, 1992)

Sub-basin #	Rill Irrigation Acreage	Sprinkler Irrigation Acreage	Big Gun Irrigation Acreage	No Irrigation Acreage
1&2	355.5	75.5	60	139
3	1,550	205	0	176
4	1,082	180	52	240
5	573	301	20	244
6	424	175	25	107

7	1,036	1,054	32	646
8	682	247	12	52

Historical Information

The FC pollution throughout the Granger Drain watershed has historically been attributed to the area's numerous livestock and concentrations of AFOs, which include various dairies. The following chronological information will demonstrate the profound nature of the FC contamination problem within the watershed:

1. Ecology's 1973 Technical Report No. 73-002*: Yakima River Water Quality Report: December 1970 – September 1971* stated that: "…there was a tendency for the coliform values at the station near the north bank at Granger [where the Granger Drain discharges into the Yakima River] to be consistently larger than those taken at the station near the south bank. This condition reached significant proportions during the summer [irrigation] quarter."

2. Ecology's April 1975 publication *Water Resources Information System Technical Bulletin No. 8* found the FC concentration in the Granger Drain to be 1,600 cfu/100 mL. The report concluded: "…it appears that bacteria present in most of the drains are of animal original…", and that "…individual farm operations are the significant cause of pollution in irrigation return flows."

3. In 1976, Ecology's publication #76-17 *Water Quality Assessment Yakima River Basin* indicated that water samples collected in the Yakima River above and below the outfall of the Granger Drain "…showed a fecal coliform increase from 370 colonies/100 mL to 510 colonies/100 mL and a total coliform increase from 6,200 to 26,000 colonies/100 mL". The FC contamination was reported as coming principally from animal sources.

4. The U.S. Army Corps of Engineers, Seattle District, (1978) wrote that when going downstream the Yakima River: "Fecal coliforms continue to increase at Toppenish (Station 8), and reach their maximum value (690 colonies/100 mL) at Station 9, immediately downstream of Granger." The FC pollution was thought to be due to the "…large concentration of confined livestock located in the Granger Drain area."

5. The *Yakima Co-operative River Basin Study* (December 1978) completed by the USDA, SCS, FSA and ASCS stated that: "Large scale confinement of livestock can cause problems with runoff water. Coliform bacterial counts in many of the area streams are in excess of state standards. In recent years, the trend toward large-scale confinement operations with a limited land base has led some people to view animal manure primarily as a waste material [not as a fertilizer material]."

6. In its June 1986 *Priority Waterbody Assessment of the Lower Yakima River*, Ecology stated that: "Irrigation return flow is the single most significant source of pollutants in the lower Yakima River." The report concluded that "…individual farm operations are the most significant cause of pollution in irrigation return flows."

7. In 1992, the USGS stated that 49% of the 200 sites located in the entire Yakima River basin, from 1968-1985, exceeded State standards for FC. The report also stated that: "Most of the [FC] exceedances in the main stem [Yakima River] occurred downstream from Granger [Drain]…[and] could be attributed to increases in the number of livestock in the basin."

8. The 1993 *Granger Drain Hydrologic Unit Annual Report* that: "The education and information exchange concerning proper manure utilization for crop growth in conjunction with proper water and commercial fertilizer management have contributed substantially to reducing bacteria loading to the Yakima River."

9. The SYCD, in its *1995-97 Water Quality Implementation/Competitive Grant Application*, stated that: "The high bacterial loading [to the Granger drain] does reflect mismanagement of animal waste in storage and application."

10. In its *Yakima Basin Fiscal Year 1997 Mid-Year Progress Report*, the USEPA (1997b) stated that: "The control of manure disposal from dairies and the management of cattle access to streams will reduce the largest contributor of fecal coliform to the Yakima River and its tributaries."

The following examples of scientific literature demonstrate why animal manure is assumed to be a principal source of excessive FC pollution in agricultural watersheds:

1. Doran and Linn (1979) observed that areas in eastern Nebraska dominated by grazing cattle and/or dairies often have surface waters containing elevated FC concentrations that are in direct relation to livestock density.

2. Crane et al. (1983) stated that: "One quality of agricultural runoff noted by several investigators is a relationship between runoff volume and bacterial density." In other words, as runoff volume increase so does the bacterial density due to "…even with higher dilution rates…the increased availability and transport of surface materials were sufficient to cause greatest bacterial contamination."

3. Edwards et al. (1997) and Lim et al. (1998) noted that agricultural practices such as cattle grazing and animal manure application can contribute to high runoff concentrations of both FC and fecal streptococcus (FS) bacteria.

4. Stoddard et al. (1998) found that besides the typical effects of surface runoff: "There can be immediate, negative effects of dairy manure application on the bacterial quality of vadose zone water."

5. Truman et al. (1998) identified in their highly statistical comparison of land uses with FC pollution (Erath County, Texas) that the greatest correlation of FC pollution occurred with both dairy manure application fields and dairy herd density ($r = 0.9100$, $p < 0.01$). The report also indicated a negative correlation with woodlands and its naturally-occurring wildlife. Their report stated that BMPs to reduce FC concentrations "…should focus on livestock."

Water Quality Assessment and Evaluation

1968-1985 USGS Surface Water Quality Assessment

The USGS (1992a) and USGS (1992b) discussed the results of FC bacterial densities collected from throughout the Yakima River Basin during the years 1968 through 1985. The data is detailed in Table 5 and indicates the historical degree and distribution of FC pollution in that basin. The report stated that a total of 2,235 FC measurements were taken from 200 sampling sites, and 49% of them were found to exceed the State's water quality standards, and that: "… sites with bacterial concentrations exceeding standards are downstream from agricultural-return flows or areas with large numbers of dairies." Interestingly, the USGS reports also stated that: "Sites in the Yakima River Basin that are minimally influenced by man's activities typically have the smallest fecal-coliform-bacteria concentrations and the fewest exceedances of State standards."

Table 5: Maximum FC Densities per Yakima River Basin Waterbody – 1972 through 1985

Sample Location	FC (cfu/100 mL)
DID #3 at South Hill Road	5
Yakima River at Cle Elum	10
DID #3 above rendering plant	25
Cle Elum River near Cle Elum	28
Yakima River near Thorp	30
Naches River at Naches	130
Naneum Creek	150
Yakima River above Cle Elum	160
Sunnyside Canal at Beam Road	160
Yakima River at Ellensburg	230*
Yakima River near Terrace Heights	230*
Yakima River at Van Geisen Bridge	340*
Yakima River at Parker	370*
Naches River near North Yakima	420*
Toppenish Creek at Alfalfa	530*
Yakima River at Umtanum	800*
Roza Canal at Beam Road	1,000*
Yakima River at Kiona	1,500*
Wide Hollow Creek	1,600*
Toppenish Creek near Satus	1,600*
Yakima River near Toppenish	1,700*
Wilson Creek at Thrall Road	1,700*
Marion Drain near Granger	1,800*
Ahtanum Creek at Union Gap	2,000*
Satus Creek at Satus	2,100*
Griffin lake Inlet	2,100*

Sample Location	FC (cfu/100 mL)
Yakima River at Prosser	2,300*
Sulphur Creek Wasteway at Duffy Road	3,000*
Yakima River at Granger	3,100*
Sulphur Creek Wasteway at McGee Road	3,200*
Cherry Creek	3,300*
Wipple Wasteway at Thrall Road	3,300*
Sulphur Creek Wasteway at Factory Road	4,000*
Yakima River at Mabton	6,100*
Wilson Creek at Sanders Road	7,000*
Wilson Creek at Dammon Road	7,900*
DID #3 at Duffy Road	8,000*
Sulphur Creek Wasteway at Morse Road	10,800*
Wilson Creek at Thrall	11,000*
Coleman Creek	17,000*
Yakima River at Union Gap	23,000*

* FC density in excess of the State's Class A water quality standards.

The USGS (1992b) report also made the first association between FC pollution and irrigated agriculture when it stated that: "The monthly fecal-coliform-bacteria concentrations for several major agricultural return flows that enter the Yakima River between Parker and Kiona (Granger and Marion Drains; and Toppenish, Satus, and Sulphur Creeks) indicate that standards are exceeded year round; however, concentrations are noticeably smaller during the low flows from September through December."

1988 USGS Bacterial Synoptic Sampling

During July 1988, the USGS conducted a synoptic survey of fecal-related bacteria, predominantly *E. coli*, at 58 surface water sites throughout the Yakima River Basin. Densities of *E. coli* and FC bacteria were found to be very similar at each site, with FC densities in the range of ½ to 2 times the respective *E. coli* densities. Table 6 details the maximum FC densities collected during the July 1988 synoptic sampling.

Table 6: Maximum FC Densities per Yakima River Basin Waterbody – 1988

Sampling Location	FC (cfu/100 mL)
Yakima River at Cle Elum	4
Yakima River at Pomona	23
Yakima River at Umtanum	27
Naches River at City of Yakima Water Treatment Plant	32
Yakima River at Kiona	35
Naches River at Naches	40
RID at Beam Road	51
Naneum Creek	55

Sampling Location	FC (cfu/100 mL)
SVID Canal at Beam Road	65
Yakima River at Union Gap	69
Chandler Canal	100
Toppenish Creek near Satus	120
Roza Canal at Gap Road	150
Cherry Creek	150
Ahtanum Creek at Union Gap	200
Yakima River at Grandview	200
Wanity Slough at Meyers Road	210*
Marion drain	210*
Yakima River at Granger	440*
Drain near Walters Road	590*
Granger Drain at sheep barn	1,300*
Moxee Drain	1,800*
East Toppenish Drain at Wilson Road	2,000*
Wide Hollow Creek	2,100*
DID #3 at Duffy Road	31,000*

* FC density in excess of the State's Class A water quality standards.

Analysis of the USGS 1988 synoptic sampling data indicated that land-use was once again an extremely important correlative factor in the distribution of *E. coli* and FC densities throughout the Yakima River Basin. In general, the average bacterial densities increased logarithmically between the observed land-use categories in the following order: forest (7 cfu/100 mL) < range-land (35 cfu/100 mL) < agriculture (87 cfu/100 mL) < agricultural return drains (750 cfu/100 mL).

The USGS report noted with special interest, the observation that bacterial densities in the Yakima River downstream of Granger increased by an order of magnitude and approximated the bacterial densities within the agricultural return drains themselves. The report stated that: "Large numbers of confined livestock and wastes in the Granger Drain area could account for the large concentrations of fecal bacteria determined in samples from the drains in this area." In fact, the largest FC density was found in DID #3 near the city of Sunnyside, which was described as flowing through "…an area in the southern part of the basin where there are large numbers of confined animals in beef and dairy cattle operations."

1992 SYCD Granger Drain Monitoring Study

The information provided by the SYCD monitoring study establishes the ambient water quality conditions in the Granger Drain watershed at the commencement of intensive BMP implementation for reducing overland runoff from irrigated agriculture, as well as improvements in dairy manure management. The study monitored the water quality of eight of the nine principal watershed sub-basins at their confluence into the Granger Drain, as well as several sites in the mainstem drain. Sub-basin #9, located to the south of the mainstem Granger Drain and across Interstate 82, was only identified near the end of the study and, therefore, had no monitoring conducted. The report also stated that the Granger Drain "…is one of the three major, agriculturally related, contributors of negative water quality [to the Yakima River]." In addition to water quality parameters, the report identified various agricultural crop and irrigation categories occurring throughout the watershed sub-basins and their respective acres (Tables 3 and 4, respectively).

A multiple regression analysis was performed comparing all of the land-use and irrigation categories detailed in Tables 3 and 4, except *flowers/berries/melon acres*, to each sub-basin's annual FC geometric mean density as detailed in Table 7.

Table 7: Annual FC Geometric mean Densities – 1992

Sub-basin #	cfu/100 mL
1&2	6,100
3	7,500
4	4,300
5	3,600
6	3,100
7	5,400
8	3,800

Analysis of the 1992 annual FC geometric mean densities per sub-basin (Table 7) indicated a highly significant ($p = 0.0028$, $r^2 = 0.8557$, $r = 0.9250$[5]) and strong correlation only with the land-use category of *dairy/feedlot acres*. The resultant equation is described and graphed below in Figure 4.

5 The most common correlation coefficient is Pearson's 'r', which is a measure of the degree of agreement between two factors. The highest possible correlation coefficient is '1' and the lowest is '0'. The strength or closeness of a correlation is found in the following table:

Pearson 'r' Value	Strength or Closeness
> 0.95	very strong
> 0.85 – 0.95	strong
> 0.75 – 0.85	moderately strong
> 0.65 – 0.75	moderate
> 0.55 – 0.65	moderately weak
0.55 or less	weak

The land-use classification of *flowers/berries/melon acres* was not included in the multiple regression analysis because only five of the eight sub-basins actually sampled had any such crop and, therefore, its inclusion in the analysis was not considered reasonable. This assessment/evaluation also considers the *dairy/feedlot acres* classification to be directly comparable to an AFO land-use classification and is defined as purely confinement acres (not including manure application areas).

FC = 2,421.92 + 39.55*X

where: FC = fecal coliform geometric mean density
X = dairy/feedlot acres

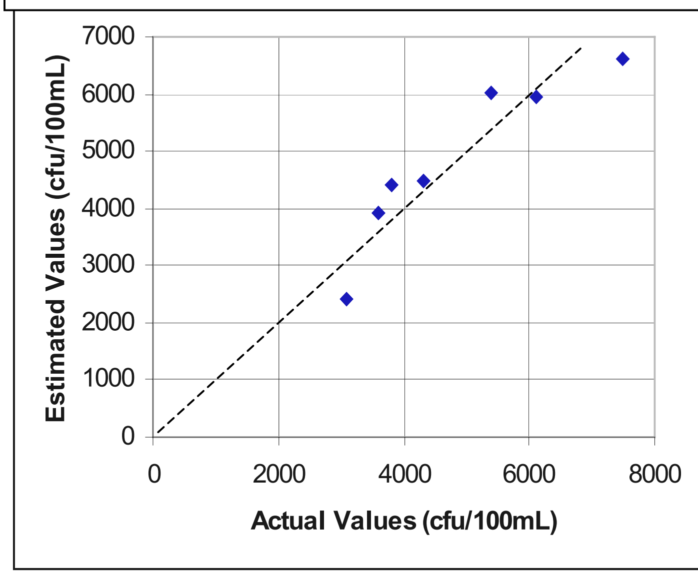

Figure 4

Estimated vs. Actual Annual FC Geometric Mean Densities per Sub-basin – 1992

The strong correlation of annual FC geometric mean densities to the single agricultural land-use parameter of *dairy/feedlot acres* seen in Figure 4 appears to substantiate the historical hypothesis that the numerous AFOs (typically dairies) are responsible for the elevated FC pollution found throughout the Granger Drain watershed, as well as a later hypothesis of the Roza-Sunnyside Board of Joint Control (April 7, 1997): "Observed FC and nutrient concentrations are related to the location of confined animal operations (dairies and feedlots) within a sub-basin."

Further analysis of FC data in the SYCD's report indicates that FC densities throughout the sub-basins during the pre-irrigation season (February and March) were statistically equivalent, and at their lowest levels. However, during the subsequent irrigation season (April through October) there occurred a significant increase in FC densities within every individual sub-basin. During the subsequent post-irrigation season (November through January), all of the sub-basins except #7 had statistically equivalent densities of FC pollution as during the pre-irrigation season. Sub-basin #7 had an increased amount of FC pollution as compared to its pre-irrigation levels.

Since FC densities were greatest during the irrigation season, a separate correlation analysis was determined justifiable for the separate irrigation season data. The analysis utilized the same crop and irrigation categories from Tables 3 and 4, which were then correlated to both geometric mean and 90th percentile FC densities determined for the various Granger Drain watershed sub-basins. The resultant data is listed in Table 8.

Table 8: Irrigation Season FC Pollution per Sub-basin – 1992

Sub-basin #	Geometric Mean Density (cfu/100 mL)	90th Percentile Density (cfu/100 mL)
1&2	15,000	160,000
3	23,800	160,000
4	15,000	160,000
5	11,800	92,000
6	8,000	92,000
7	8,500	22,000
8	13,400	160,000

Multiple regression analysis of only the irrigation season's FC geometric mean densities (Table 8) vs. the various crop and irrigation categories from Tables 3 and 4 determined the existence of a highly significant ($p = 0.0006$, $r^2 = 0.9950$, $r = 0.9975$) and very strong correlation with the combination of three crop categories. The linear equation is described and graphed below in Figure 5.

$$FC = 10{,}242.90 + 21.83*X + 41.51*Y - 11.42*Z$$

where: FC = fecal coliform geometric mean density
X = corn/wheat acres
Y = dairy/feedlot acres
Z = alfalfa/pasture acres

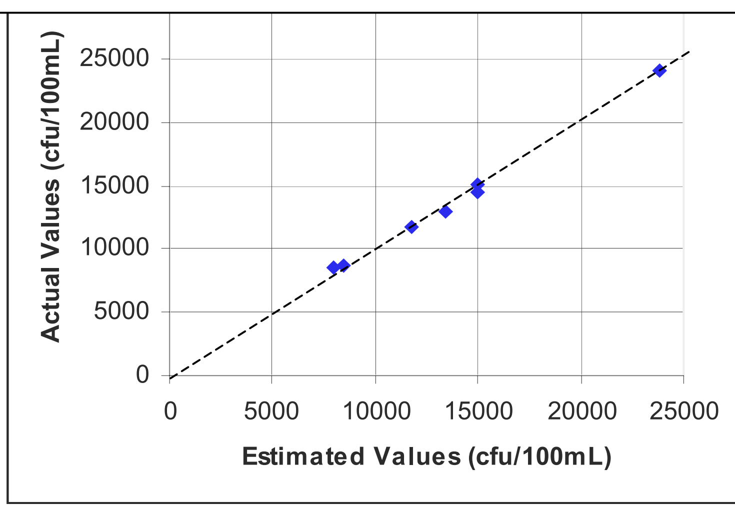

Figure 5

Estimated vs. Actual Irrigation Season FC Geometric Mean Densities per Sub-basin – 1992

The previous importance of *dairy/feedlot acres* originally found with the annual FC geometric mean data (Figure 4) continues to exist when considering only the irrigation season data (Table 8). From the above equation, *dairy/feedlot acres* is identified as having the largest correlation with FC geometric mean densities; however, two other crop categories (*corn/wheat acres* and *alfalfa/pasture acres*) also correlate to the amount of FC pollution found within each sub-basin. *Corn/wheat acres* is positively correlated to FC densities, while *alfalfa/pasture acres* is negatively correlated. It is assumed that a main difference between these two crop categories is that *corn/wheat acres* has significantly more overland runoff due to rill irrigation than that from sprinkler-irrigated *alfalfa/pasture acres*. The latter crop category probably also acts as a buffer for filtering any associated runoff must pass through it. Such buffering capacity of the *alfalfa/pasture acres* supports the hypothesis that overland runoff from manured irrigated agriculture is a principal transport mechanism and source of FC pollution to the mainstem Granger Drain, through its adsorption to suspended sediment particles. Another aspect of why *corn/wheat acres* and *alfalfa/pasture acres* are so determinative of FC pollution is that together they represent the majority (54%) of the total agricultural acres in the Granger Drain watershed.

An additional regression analysis found a similar highly significant ($p = 0.0075$, $r^2 = 0.9729$, $r = 0.986$) and very strong correlation between FC densities and *dairy/feedlot acres* plus two irrigation parameters: *rill irrigation acres* and *sprinkler irrigation acres*. Such parameters also give support to the hypothesis that overland runoff from irrigated agriculture, principally rill irrigation, transports large densities of FC pollution by adsorption to suspended sediment. (Rill irrigation also covers 58% of the watershed's total area; while, sprinkler irrigation covers only 24%). The linear equation for the correlation is described and graphed below in Figure 6.

FC = 7,491.32 + 73.46*X + 6.62*Y – 11.61*Z

where: FC = fecal coliform geometric mean density
X = dairy/feedlot acres
Y = rill irrigation acres
Z = sprinkler irrigation acres

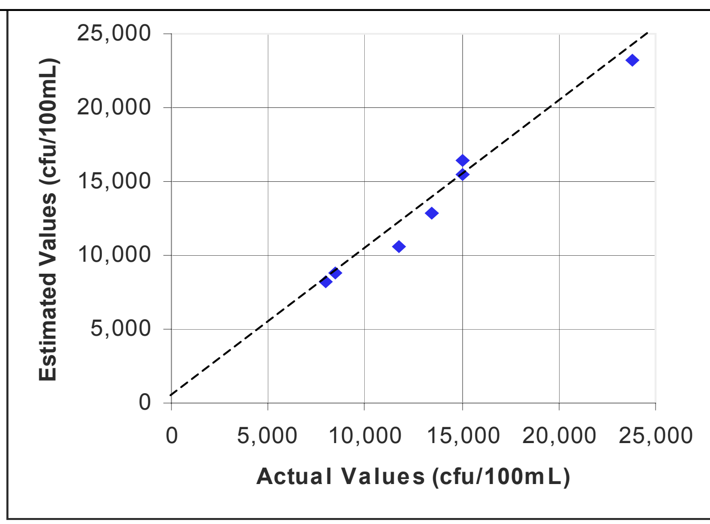

Figure 6

Estimated vs. Actual Irrigation Season FC Geometric Mean Densities per Sub-basin – 1992

From analysis of Figures 5 and 6, it was determined that replacement of the *corn/wheat acres* and *alfalfa/pasture acres* crop parameters with the irrigation methods of *rill irrigation acres* and *sprinkler irrigation acres* resulted in a similar correlation. However, the type of crop appears to have a greater bearing on estimating final FC densities than does irrigation type (note the large numerical value in front of *corn/wheat acres* category as compared to that of *rill irrigation acres* in their respective linear equations). This may be a result of the fact that various irrigation methods can be utilized for any single crop, whereas manure (source of FC pollution) application rates are typically crop specific.

In any event, the positive correlation of FC densities to the amount of *rill irrigation acres* supports the assumption that such irrigation method produces overland runoff containing both suspended sediment and adsorbed FC bacteria. Likewise, the negative correlation between FC densities and *sprinkler irrigation acres* probably indicates that such irrigation method produces less, if any, overland runoff and is typically associated with crops (alfalfa/pasture) that act as a buffer to diminish sediment/FC densities in whatever runoff exists. Both of the above assumptions give support to this assessment/evaluation's hypothesis that overland runoff from irrigated agriculture is a principal transport mechanism of FC pollution.

The linear equations for Figures 5 and 6 suggest that *dairy/feedlot acres* is correlated to a more concentrated FC pollution, while less concentrated FC pollution is related to both *corn/wheat acreage* and *rill irrigation acres*. This idea comes from the fact that the largest numerical factors (41.51 and 73.46) in the equations were associated with the same single parameter of *dairy/feedlot acres*. Although a finding of significant correlation does not, by itself, prove a causal relationship (and visa versa) between two parameters, it is a fact that FC bacteria are present in manure, which is produced in large quantities at dairies and feedlots. Thus, it can be safely assumed that dairies and feedlots are important sources of a raw material (manure) that contains numerous FC bacteria (Table 2). Although the source of the FC correlated to *dairy/feedlot acres* is most probably cow manure, the source of the FC pollution correlated to the corn/wheat crop and rill irrigation acreage is hypothesized to be the agricultural applications of cow manure, although the exact animal source has not yet been proven.

The next set of multiple regression analyses were conducted using the non-irrigation season geometric mean and 90^{th} percentile FC densities from Table 9 compared to the various crop and irrigation categories as listed in Tables 3 and 4.

Table 9: Non-irrigation Season FC Pollution per Sub-basin – 1992

Sub-basin #	Geometric Mean Density (cfu/100 mL)	90^{th} Percentile Density (cfu/100 mL)
1&2	1,170	16,000
3	870	9,200
4	430	2,200
5	400	2,200
6	520	2,200
7	2,000	9,200
8	440	2,200

The multiple regression analyses of only the non-irrigation season FC densities for the various sub-basins of the Granger Drain watershed vs. the same crop parameters and irrigation methods indicated no significant correlations. Future analyses of non-irrigation season correlations with specific land-use categories should still be conducted in order to determine what, if any, land-uses might become correlated to the non-irrigation season FC pollution. The complete lack of correlation during the non-irrigation season, also supports this assessment/evaluation's hypothesis that overland runoff from irrigated agriculture is a principal transport mechanism of FC pollution throughout the watershed.

Interestingly, a second principal transport mechanism for FC in the Granger drain watershed was identified from the SYCD report. That transport mechanism was identified as subsurface drainage, which was collected at sampling site MHWB (Manhole West Blvd.[6]) and represented the agricultural drainage from sub-basin #8. Analysis of that site's data compared to the other sites determined that there was no significant (ANOVA, $p = 0.5770$) difference between any of the FC densities collected. Therefore, this assessment/evaluation considers subsurface drainage just as important as surface drainage water in terms of transporting FC pollution to the mainstem Granger Drain.

The extreme difference between the actual geometric mean and 90^{th} percentile FC densities listed in Table 8 (irrigation season) vs. those in Table 9 (non-irrigation season) dramatically illustrate the seasonality of FC pollution throughout the watershed. That data also substantiates, in a general sense, the hypothesis that the FC pollution throughout the Granger Drain watershed is dependent upon irrigated agriculture, since the greatest FC densities are always associated with the irrigation season.

1995 Ecology Fecal Coliform Monitoring

1. Granger Drain Watershed Sub-basins

   Ecology conducted FC monitoring of the Granger Drain watershed sub-basins, at their confluence to the mainstem Granger Drain, only during the irrigation season (April through October) of 1995. Table 10 compares the geometric mean and 90^{th} percentile FC densities between the irrigation seasons of 1992 and 1995. However, a strict comparison of the 1992 (Appendix A) and 1995 (Appendix B) FC densities may not be entirely valid. This is due to: (1) some of the 1992 data was *estimated* to be greater than, or less than, a specific value; however, such values were utilized herein without regard to their descriptor; and (2) the 1995 data was analyzed according to the most probable number (MPN) laboratory methodology, whereas, all other data was analyzed using the membrane filter (MF) technique. This assessment/evaluation assumes that its final conclusions will not be seriously affected by the above conflicts.

[6] Manhole West Blvd. is described as being located in the town of Granger, 30 yards North of the intersection of West Blvd. and West 1st Ave. on the East side of the roadway in an empty lot (as of 1992).

Table 10 details the geometric mean and 90th percentile FC densities for both 1992 and 1995, as well as the respective FC reductions in the Granger Drain sub-basins. The reductions ranged from 68% to 89% for irrigation season geometric mean densities, and from 68% to 97% for 90th percentile densities. The greatest percent reductions occurred in sub-basin #1&2 (89% and 96%, respectively); while the least reduction occurred in sub-basins #6 (68% and 92%, respectively) and #7 (81% and 68%, respectively).

Table 10: Comparison of Irrigation Season FC Geometric Mean and 90th Percentile Densities (cfu/100 mL) – 1992 and 1995

	Granger Drain Watershed Sub-basin					
Date & Parameter	**#1&2**	**#3**	**#4**	**#5**	**#6**	**#7**
1995 Geometric Mean	1,690	5,820	2,860	2,520	2,600	1,610
1992 Geometric Mean	15,000	23,800	15,000	11,800	8,000	8,500
% Change from 1992	- 89	- 76	- 81	- 79	- 68	- 81
1995 90th Percentile	7,000	17,000	4,900	7,150	7,000	7,000
1992 90th Percentile	160,000	160,000	160,000	92,000	92,000	22,000
% Change from 1992	- 96	- 89	- 97	- 92	- 92	- 68

As no updated land-use survey was available for 1995, the above FC data was correlated only to a set of dairy-related parameters that was submitted in 1996 by the individual dairy facilities in the Granger Drain watershed. Table 11 presents those dairy-related parameters that have been corrected to reflect the fact that some of the drainages within sub-basins #3 and #7, located between the SVID and RID canals, actually discharge into the SVID canal rather than into the mainstem Granger Drain during the irrigation season. If such corrections were not made, the results obtained would be based on erroneous data.

Table 11: Irrigation Season Dairy-related Parameters and FC Densities – 1996

Sub-basin #	Dairy Acres (#)	Cows (#)	Heifer Repl. & Calves (#)	Total Animals (#)	Animals per Acre (#)	FC Geometric Mean Densities (cfu/100 mL)	FC 90th Percentile Densities (cfu/100 mL)
1&2	180	1,150	860	2,010	11.17	1,690	7,000
3	1,105	3,963	797	4,750	4.30	5,820	17,000
4	40	500	100	600	15.00	2,860	4,900
5	450	1,816	891	2,707	6.02	2,520	7,150
6	90	1,430	1,000	2,430	27.00	2,600	7,000
7	735	2,745	1,250	3,995	3.62	1,610	7,000

After multiple regression analysis, only the # *cows* had a significant ($p = 0.0124$, $r^2 = 0.7506$, $r = 0.866$) and strong correlation to the respective sub-basin FC 90th percentile densities (no correlations were found with FC geometric mean densities). The resultant equation is described and graphed below in Figure 7.

FC = 2,503.77 + 3.02*X

where: FC = fecal coliform 90th percentile density

X = # cows

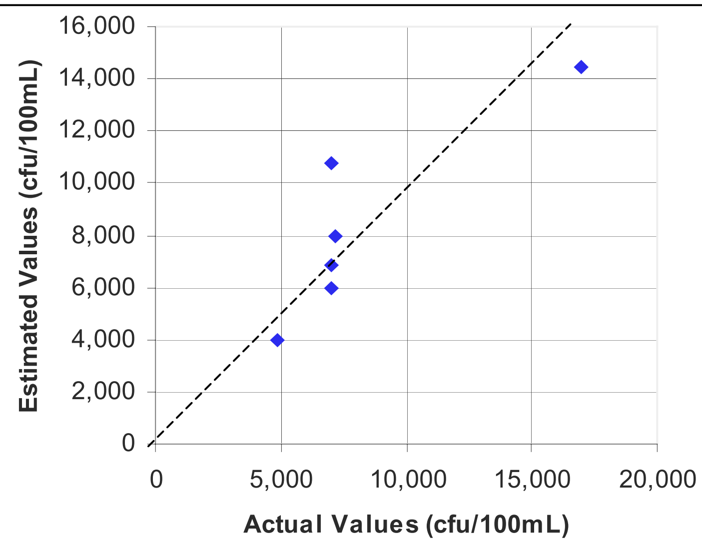

Figure 7

Estimated vs. Actual Irrigation Season FC 90th Percentile Densities per Sub-basin – 1995

The determination that only the worst case FC pollution episodes (90th percentile densities) were related to dairy parameters is quite a significant departure from the results of the SYCD's earlier data, which indicated that dairy-related parameters were correlated to the average (geometric mean) FC pollution within the watershed. The decreasing trend from 1992 to 1995 suggests a substantial improvement in the management of manure at the Granger Drain watershed dairies.

This assessment/evaluation will repeat similar regression analyses in later sections using the 1998 and 2000 dairy-related data in order to determine if on-site dairy-related parameters continue to be correlated to average or worst-case FC pollution in the Granger Drain watershed.

2. Mainstem Granger Drain

Analysis of individual sections of the mainstem Granger Drain during 1995, presented in Table 12, indicated large FC densities; however, they were significantly less than those of 1992. The FC geometric mean percent reduction values ranged from 45% to 88%; while the FC 90th percentile percent reduction values varied from 79% to 96%.

Table 12: Comparison of Irrigation Season FC Geometric Mean and 90th Percentile Densities (cfu/100 mL) – 1992 and 1995

	Mainstem Granger Drain Location			
Date & Parameter	**Post-Sub-basin #3**	**Post-Sub-basin #5**	**Post-Sub-basin #6**	**Post-Sub-basin #7**
1995 Geometric Mean	4,460	5,430	3,670	1,550
1992 Geometric Mean	15,800	9,900	10,300	12,500
% Change from 1992	- 72	- 45	- 64	- 88
1995 90th Percentile	24,000	10,950	7,900	4,900
1992 90th Percentile	160,000	51,000	160,000	120,000
% Change from 1992	- 85	- 79	- 95	- 96

The post-sub-basin #7 mainstem section had the highest reduction in FC pollution, while the post-sub-basin #5 section had the worst reduction. That low FC reduction may have been caused by the potential addition of FC pollution from sub-basin #9, which is located to the south of the mainstem Granger Drain and presumably enters the drain in the area of the post-sub-basins #5 and #6 sampling sites. Another potential scenario could be large FC densities coming from sub-basins #4 and #5. The last (downstream) mainstem Granger Drain sampling site (post-sub-basin #7 = site #24) is located at the old sheep barn facility located just within the town of Granger, and represents the extent of predominant agriculture land-use in the watershed. At the sheep barn site, since 1992, the mainstem Granger Drain FC geometric mean and 90th percentile FC densities have decreased by 88% and 96%, respectively.

Although the mainstem Granger Drain travels through the town of Granger before it discharges into the Yakima River, no monitoring samples have been collected downstream of that town. Therefore, monitoring of the mainstem Granger Drain downstream of the town of Granger will be required by the *Granger Drain Fecal Coliform Bacteria TMDL* as a condition for assuring compliance of the entire mainstem Granger Drain with the applicable water quality standards. The downstream sampling site will be utilized for determining the amount, if any, FC pollution in the mainstem Granger Drain that can be attributable to urban sources.

3. SVID and RID Canal Water

During the 1995 study, FC densities were also monitored in both the SVID and RID irrigation water supply canals in order to describe the quality of the irrigation water supplied to, and leaving from, the Granger Drain watershed. The SVID canal was sampled at both Beam Road (*entrance*) and Maple Grove Road (*downstream*); while, the RID canal was sampled at both Beam Road (*entrance*) and Ray Road (*downstream*). Table 13 details the statistical summary of the FC densities collected from the SVID canal water. Subsequent statistical analysis indicated that significantly (paired t-test, $p = 0.0219$) greater FC pollution exists in the *downstream* section of the SVID canal.

Table 13: SVID Canal Water FC (cfu/100 mL) Statistics – 1995

Date or Parameter	Entrance	Downstream
April 10	11	13
April 25	2	7.8
May 8	31	23
May 22	33	180
June 5	490	490
June 19	140	79
July 5	70	330
July 17	110	140
August 1	46	240
August 14	23	330
August 28	130	130
September 12	230	170
September 25	31	170
October 17	N/A	790
Geometric Mean	50	123
90th Percentile	230	490

Table 14 details the statistical summary of the FC densities collected from the RID canal water. A statistical analysis indicated no significant (paired t-test, $p = 0.6665$) difference between the FC densities in the *entrance* and *downstream* sections of the RID canal.

Table 14: RID Canal Water FC (cfu/100 mL) Statistics – 1995

Date or Parameter	Entrance	Downstream
April 10	17	31
April 25	2	1.8
May 8	4.5	11
May 22	49	79
June 5	110	70
June 19	23	240
July 5	49	33
July 17	33	49
August 1	49	49
August 14	790	79
August 28	33	33
September 12	230	49
September 25	230	33
October 17	N/A	79
Geometric Mean	44	39
90th Percentile	230	79

Subsequent statistical analysis of FC densities throughout the entire SVID and RID canals determined that the SVID canal contained significantly (paired t-test, $p = 0.0211$) greater FC pollution than the RID canal. In order to determine the source of the SVID pollution, a comparison was made of the FC densities in the *entrance* sections of the separate canals. As no significant (paired t-test, $p = 0.7649$) difference was found between the *entrance* FC densities, the FC pollution delivered to the two canals is considered statistically equivalent. Therefore, the greater FC pollution found in the *downstream* section of the SVID canal must be derived from direct discharges into that canal, subsequent to its *entrance* section.

From Tables 13 and 14, it was determined that only the Class A FC 90th percentile standard was not being met during 1995 in the entrance section SVID and RID irrigation water to the Granger Drain watershed. As this water comes directly from the Yakima River, it is hoped that as other upstream watersheds have TMDLs initiated and BMPs implemented, the FC pollution entering the Granger Drain watershed by means of the two canals will eventually improve to meet State standards. It was also observed that both of the Class A FC standards were not being met by the SVID canal's downstream section. The watershed's irrigation canals are required to meet State water quality standards because such man-made canals are considered "waters of the United States" by several court cases. Those cases are: *United State v. Holland* (373 F. Supp. 665, 673), *Weizman* *v. District Engineer* (526 F. 2d. 1302, 1305), *United States v. Ottati & Gross, Inc.* (630 F. Supp. 1361, 1401), *United States v. Pozsgai* (999 F. 2d 719, 731), and most recently, *Community Association for Restoration of the Environment v. Henry Bosma Dairy et al.* (65 F. 2d. 1129).

1997, 1998, 1999 and 2000 RSBOJC Fecal Coliform Monitoring

The Roza-Sunnyside Board of Joint Control (RSBOJC) began extensive monitoring throughout the Granger Drain watershed in 1997. The agency has continued to monitor the surface waters of the watershed on a year-round basis. In addition, the SVID and RID irrigation water supply canals were monitored during 1998, 1999 and 2000. The greatest amount of FC pollution throughout the years was consistently observed during the irrigation seasons. Statistical analyses revealed an exceptionally strong seasonality in FC pollution found between the irrigation and non-irrigation seasons (t-tests: $p = 1.06 \times 10^{-15}$, 1.37×10^{-13}, 1.76×10^{-11}, and 0.0217, respectively). This supports similar observations made from the data presented in the 1992 SYCD report, discussed earlier.

1. Irrigation Seasons

Table 15 presents the FC geometric mean densities and associated percent reductions for the Granger Drain watershed sub-basins calculated using only the irrigation season monitoring data collected from the 1992 through 2000 water years. Similarly, Table 16 details the FC 90th percentile densities throughout the watershed during the irrigation seasons for the same period of time.

Table 15: Irrigation Season FC Geometric Mean Densities (cfu/100 mL) and % Reductions for Sub-basins – 1992 through 2000

% Reduction	Sub-basin	RSBOJC				Ecology	SYCD
1992 – 2000	#	2000	1999	1998	1997	1995	1992
> 93	1&2	*	*	1,020	*	1,690	15,000
98	3	310	810	1,510	950	5,820	23,800
94	4	970	1,330	1,640	3,690	2,860	15,000
90	5	1,140	3,240	2,030	723	2,520	11,800
88	6	1,000	1,010	1,560	2,280	2,600	8,000
97	7	230	1,150	900	1,610	1,610	8,500

* Not enough sampling data available to calculate.

Table 16: Irrigation Season FC 90th Percentile Densities (cfu/100 mL) and % Reductions for Sub-basins – 1992 through 2000

% Reduction 1992 - 2000	Sub-basin #	RSBOJC 2000	RSBOJC 1999	RSBOJC 1998	RSBOJC 1997	Ecology 1995	SYCD 1992
> 98	1&2	*	*	2,500	*	7,000	160,000
99	3	1,600	6,000	4,200	7,700	17,000	160,000
98	4	2,700	5,000	5,300	18,000	4,900	160,000
97	5	2,600	13,000	10,000	5,500	7,150	92,000
96	6	3,600	3,800	6,200	24,000	7,000	92,000
97	7	600	10,000	2,850	33,000	7,000	22,000

* Not enough sampling data available to calculate.

Since 1992, all of the individual sub-basin geometric mean and 90th percentile FC densities have decreased dramatically, with all but one of the sub-basin percent reductions being greater than 90%. The majority of the year-2000 geometric mean and 90th percentile FC densities are significantly lower than during 1999, but they still are all at least 11 times larger than the Class A FC water quality standards (100 cfu/100 mL = geometric mean, 200 cfu/100 mL = 90th percentile).

Tables 17 and 18 detail the dairy-related data for the 1998 and 2000 irrigation seasons, respectively, which will be used to determine if any significant correlations with FC pollution are apparent as similar to the 1995 data. The dairy-related information presented in those tables have been corrected to exclude data pertaining to specific sub-basin drainages that do not actually discharge into the mainstem Granger Drain during the irrigation season, but rather into the SVID canal. Such discharges are the probable source of FC pollution that has been observed in the *downstream* SVID canal when compared to the *entrance* section of that canal at Beam Road. Due to such FC pollution, all points in the SVID irrigation water supply canal will be included as points of compliance for the *Granger Drain Fecal Coliform Bacteria TMDL*.

Table 17: Irrigation Season Dairy-related Parameters and FC Pollution – 1998

Sub-basin #	Dairy Acres (#)	Cows (#)	Heifer Repl. & Calves (#)	Total Animals (#)	Animals per Acre (#)	FC Geometric Mean Density (cfu/100 mL)	FC 90th Percentile Density (cfu/100 mL)
1&2	150	1,125	900	2,025	13.50	1,020	2,500
3	1,003	5,994	401	6,395	6.38	1,510	4,200
4	800	450	0	450	0.56	1,640	5,300
5	676	1,625	1,200	2,825	4.18	2,030	10,000
6	600	2,000	1,500	3,500	5.83	1,560	6,200
7	711	2,665	1,120	3,785	5.32	900	2,850

Table 18: Irrigation Season Dairy-related Parameters and FC Pollution – 2000

Sub-basin #	Dairy Acres (#)	Cows (#)	Heifer Repl. & Calves (#)	Total Animals (#)	Animals per Acre (#)	FC Geometric Mean Density (cfu/100 mL)	FC 90th Percentile Density (cfu/100 mL)
1&2	162	1,249	901	2,150	13.27	*	*
3	1,504	4,167	535	4,702	3.13	310	1,600
4	28	520	175	695	24.82	970	2,700
5	676	1,700	600	2,300	3.40	1,140	2,600
6	90	1,600	700	2,300	25.56	1,000	3,600
7	930	2,840	1,030	3,870	4.16	230	600

* Not enough sampling data available to calculate.

After performing a multiple regression analysis of both the 1998 and 2000 irrigation season data (Tables 17 and 18), none of the dairy-related parameters were found to have a significant correlation with either the sub-basin geometric mean or 90th percentile FC densities. This demonstrates a continued decreasing trend of on-site dairy operations to be correlated to FC pollution in the Granger Drain watershed. The present non-existence of significant correlations suggests that on-site dairy-related parameters are probably not now actual sources of FC pollution during the irrigation season, as they once were determined to have been. The recent lack of correlation is presumed to be the result of continued implementation of improved manure management on dairy facilities, both voluntarily and required, as well as the enactment of the State's *1998 Dairy Nutrient Management Act*.

Even though dairy-related parameters are not presently correlated to FC densities in the watershed's surface waters, it is still assumed that manured irrigated agriculture will be correlated due to the fact that FC bacteria adsorb to the fine suspended sediment in overland runoff. Agricultural land-use data for the year 1999 was recently received from WSUCE and is detailed in Table 19.

Table 19: 1999 Agricultural Land-use (WSUCE)

Sub-basin #	Annual Acres (#)	Corn Acres (#)	Dairy Acres (#)	Hops Acres (#)	Row Crop Acres (#)	No Crop Acres (#)	Pasture Acres (#)	Permanent Acres (#)
1&2	66.7	631.9	103.6	384.4	680.3	604.0	983.8	729.3
3	0	533.6	78.4	0	360.9	249.8	465.3	111.9
4	9.2	557.8	28.8	0	571.0	270.2	434.2	380.1
5	114.9	1,088.3	110.1	0	1,154.4	203.7	141.5	158.5
6	52.4	181.6	139.9	0	513.3	48.5	5.9	0
7	0	150.2	91.4	0	80.7	64.2	20.3	0

Since land-use data is not available for each year, multiple regression analyses were made utilizing the data in Table 19 vs. the 1999 and 2000 irrigation season FC geometric mean and 90th percentile densities per Granger Drain watershed sub-basin. In each of those analyses, the land-use category of *hops acres* was not included as that crop type was limited to only two of the watershed's sub-basins. The regression analyses concerning the 1999 FC geometric mean densities indicated that only three of the above land-use categories were significantly ($p < 0.10$) correlated to those densities. The three categories and their statistical probabilities are detailed in Table 20.

Table 20: Irrigation Season Regression Probabilities for FC Geometric Mean Densities – 1999

Land-Use Category	'r'	Probability (p)	Linear Equation
Annual Acres	0.87	0.0402	334.96 + 2.19*X
Row Crop Acres	0.85	0.0413	398.07 + 2.21*X
Corn Acres	0.88	0.0575	891.19 + 17.47*X

Even though the land-use categories were from the year 1999, such data is assumed to have had a negligible change for the year 2000 data. Thus, the same land-use data was also utilized for the regression analyses concerning the 2000 FC geometric mean densities. Those analyses indicated that only one of the above (Table 19) land-use categories was significantly ($p < 0.10$) correlated to FC geometric mean densities throughout the Granger Drain watershed. That category and its statistical probability are detailed in Table 21.

Table 21: Irrigation Season Regression Probabilities for FC Geometric Mean Densities – 2000

Land-Use Category	'r'	Probability (p)	Linear Equation
Row Crop Acres	0.83	0.0711	250.04 + 0.90*X

No significant correlations relating to the 1999 or year-2000 FC 90th percentile densities were found.

The above correlations of the 1999 and 2000 FC geometric mean densities vs. agricultural land-use categories (Table 18) and especially the consistent correlation to the category *row crop acres,* support this assessment/evaluation's hypothesis that overland runoff from irrigated agriculture, especially rill irrigation, is a principal transport mechanism of FC pollution. However, it should also be noted that the probability "p" associated with the row crop correlation has decreased substantially from 1999 (0.0413) to the year 2000 (0.0711). Such decrease suggests that the BMPs for controlling suspended solids overland runoff from irrigated agriculture are continuing to have a measurable improvement (reduction) in FC pollution being transported off those areas.

Table 22 details the average daily discharge observed throughout the sub-basins of the Granger Drain watershed during the 1992 through 2000 irrigation seasons, which had an overall percent reduction ranging from 25% to 85%. However, since 1997 the irrigation season discharges have been relatively stable.

Table 22: Irrigation Season Average Daily Discharge (cfs) for Sub-basins – 1992 through 2000

% Reduction 1992 - 2000	Sub-basin #	RSBOJC 2000	RSBOJC 1999	RSBOJC 1998	RSBOJC 1997	Ecology 1995	SYCD 1992
> 6	1&2	*	*	3.2	*	3.0	3.4
85	3	2.7	2.6	2.7	3.4	12.3	17.5
25	4	7.1	3.4	7.7	9.5	6.1	9.5
42	5	5.1	5.4	4.7	*	4.6	8.8
64	6	2.4	2.7	2.5	2.2	3.0	6.6
25	7	7.7	8.6	8.1	9.1	5.7	10.2

* Not enough data collected for calculation.

Table 23 presents the detailed characteristics of the physical location for all of the water quality sampling sites in the mainstem Granger Drain.

Table 23: Mainstem Granger Drain Sampling Sites

Mainstem Sampling Site #	Represents Post Sub-basin #	Location of Sampling Site
23	3	South of Yakima Valley Highway, ¼ mile west of Dekker Road and 50 feet upstream of the confluence of joint drain 32.0 and irrigation drain DR-2.
13	5	South of Yakima Valley Highway, at the end of Liberty Road where the main drain is culverted under the railroad access road.
7.5	6	Southwest of Yakima Valley Highway, 70 feet west of Beam Road. (Replaces sampling site #8 beginning with year-2000 irrigation season).
8	6	Southwest of Yakima Valley Highway, 150 feet west of Beam Road where the main drain passes through a 7-ft culvert under the railroad access road.
24	7	At sheep barn, in the town of Granger where the main drain passes under the dirt road between the former sheep barn and truck weigh scale.

Tables 24 and 25 summarize the mainstem Granger Drain geometric mean and 90^{th} percentile FC densities, as well as their respective percent reductions, during the irrigation season.

Table 24: Irrigation Season FC Geometric Mean Densities (cfu/100 mL) and % Reductions for Mainstem Granger Drain – 1992 through 2000

% Reduction 1992 - 2000	Mainstem Sampling Site #	RSBOJC				Ecology	SYCD
		2000	1999	1998	1997	1995	1992
98	23	290	1,330	950	1,830		15,800
*	13	*	*	*	1,480	5,430	9,900
91	8/7.5**	920	*	*	1,600	3,670	10,300
94	24	750	1,200	980	1,340	1,550	12,500

* Not enough sampling data available to calculate.
** Sampling sites #8 and #7.5 are essentially the same location: #7.5 replaced #8 in 2000.

Table 25: Irrigation Season FC 90th Percentile Densities (cfu/100 mL) and % Reductions for Mainstem Granger Drain – 1992 through 2000

% Reduction 1992 - 2000	Mainstem Sampling Site #	RSBOJC				Ecology	SYCD
		2000	1999	1998	1997	1995	1992
99	23	1,200	3,300	2,200	15,000	24,000	160,000
*	13	*	*	*	3,300	10,950	51,000
99	8/7.5**	1,700	*	*	4,800	7,900	160,000
99	24	1,200	2,200	2,100	4,000	4,900	120,000

* Not enough sampling data available to calculate.
** Sampling sites #8 and #7.5 are essentially the same location: #7.5 replaced #8 in 2000.

From Tables 24 and 25, the latest geometric mean and 90th percentile FC densities collected from the mainstem Granger Drain, during the irrigation season, were significantly less than previous years. However, they still are 9 and 8.5 times greater, respectively, than the corresponding Class A standards. The year-2000 FC geometric mean densities ranged from 290 to 920 cfu/100 mL with percent reductions, since 1992, ranging from 91% to 98%. The latest FC 90th percentile densities ranged from 1,200 to 1,700 cfu/100 mL and at a constant 99% reduction from 1992. During the year 2000, the mainstem Granger Drain geometric mean and 90th percentile FC densities are considered abnormally high at sampling site #8/7.5 when compared to that of the upstream site (#23).

The increased FC pollution could have been introduced from sub-basins #4 and #5 or derived from sub-basin #9, which is located to the south of the mainstem Granger Drain across Interstate 82. Analysis of Tables 15, 16 and 22 shows that the FC densities within sub-basins #4 and #5 are normal, but their flows are significantly higher than the other sub-basins, which suggests that those sub-basins may indeed be the problem. However, sub-basin #9 is probably another source of FC bacteria as it contains AFOs and will thus need to be monitored to determine the extent of its FC pollution contribution.
The historic sampling site located just within the town of Granger at the old sheep barn (RSBOJC sampling site #24) has special importance to the TMDL, since it represents the end of predominantly agricultural discharges into the mainstem Granger Drain.

Accordingly, any sampling site downstream of #24 will probably be also influenced to some degree by urban runoff from the town of Granger. The TMDL will require monitoring FC pollution throughout the entire mainstem Granger Drain, as well as SVID and RID canals, since that is where the TMDL's points of compliance are located. The Summary Implementation Schedule (SIS) for the TMDL will need to incorporate monitoring of the entire mainstem Granger Drain including the section downstream of the town of Granger, which has yet to be monitored on a regular basis, in order to assure compliance with the TMDL requirements.

2. Non-irrigation Seasons

Table 26 details the FC geometric mean densities observed, including percent reductions, during the 1992 through 2000 non-irrigation seasons.

Table 26: Non-irrigation Season FC Geometric Mean Densities (cfu/100 mL) and % Reductions for Sub-Basins – 1992 through 2000

% Reduction	Sub-basin	RSBOJC				Ecology	SYCD
1992 - 2000	#	2000	1999	1998	1997	1995	1992
> 50	1&2	*	*	590	*	*	1,170
89	3	100	80	170	190	*	870
66	4	148	130	780	1,050	*	430
98	5	8	8	30	6	*	400
38	6	322	1,080	300	1,310	*	520
98	7	34	50	380	60	*	2,000

* Not enough sampling data available to calculate.

Table 26 indicates that since 1992, the non-irrigation season FC geometric means percent reductions have ranged from 38% to 98%. A comparison of the data from Table 15 with the above data indicates that during the non-irrigation seasons there was typically found approximately 85% less FC pollution throughout the watershed than during the respective irrigation seasons. This illustrates the seasonality of the FC pollution within the surface drainage systems of the Granger Drain watershed. As AFOs are expected to be managed fairly consistently throughout the year, their on-site FC pollution should not vary on a seasonal basis.

The disparity of FC geometric mean pollution between the irrigation and non-irrigation seasons can only be reasonably attributed to irrigated agriculture. It should also be noted that the FC geometric mean densities for sub-basins #3, #5 and #7 were in compliance with the respective Class A FC water quality standard (100 cfu/100 mL) during the 1999 and 2000 non-irrigation seasons. This has special significance, since sub-basins #3 and #7 also have the largest number of dairy cows in the entire watershed.
Table 27 details the FC 90th percentile densities observed, including percent reductions, during the 1992 through 2000 non-irrigation seasons.

Table 27: Non-irrigation Season FC 90th Percentile Densities (cfu/100 mL) and % Reductions for Sub-Basins – 1992 through 2000

% Reduction	Sub-basin	RSBOJC				Ecology	SYCD
1992 - 2000	#	2000	1999	1998	1997	1995	1992
> 76	1&2	*	*	3,800	*	*	16,000
99	3	100	180	2,000	620	*	9,200
81	4	410	640	2,800	2,300	*	2,200
98	5	34	62	63	31	*	2,200
- 95	6	4,300	6,000	430	5,800	*	2,200
99	7	92	1,300	1,000	1,100	*	9,200

* Not enough sampling data available to calculate.

Table 27 indicates that since 1992, the non-irrigation season FC 90th percentile percent reductions have ranged from 0% (actually a 95% increase) to 99%. The increase of FC pollution in sub-basin #6 is assumed to be an abnormality, since all the other sub-basins have had FC reductions. The source of the anomalous FC pollution warrants further investigation. The corresponding sampling site is located on a tributary drain, which crosses Van Belle Road, just west of North Liberty Road.

Once again, it should be noted that during the 2000 non-irrigation season the FC 90th percentile densities for sub-basins #3, #5 and #7 were in compliance with the Class A FC water quality standard (200 cfu/100 mL). Interestingly, sub-basin #7 effectively contains 4.5 times as many dairy cows during the non-irrigation season (Table 29) as compared to the irrigation season (Table 18) due to changes in sub-basin drainage patterns as discussed on page 26. Even so, sub-basin #7 was still able to comply with the State's Class A FC water quality standard during the non-irrigation season. Whereas, during the irrigation season sub-basin #7, with significantly fewer cows, did not comply with those standards. This supports the assumption that on-site dairy operations, such as the number of animals maintained, are not presently responsible for FC pollution; but rather, such pollution is caused by other parameters specifically related to the irrigation season. All of the above data strongly supports this assessment/evaluation's hypothesis that overland runoff from manured irrigated agriculture, especially rill irrigation, is the principal transport mechanism and source of FC pollution to the mainstem Granger Drain.

Tables 28 and 29 detail the dairy-related parameters for the 1998 and 2000 non-irrigation seasons, respectively, which were analyzed to determine their potential correlations with FC pollution. The data in both those tables have been corrected to exclude dairy-related data that do not pertain to the mainstem Granger Drain due to the phenomenon detailed above, which causes significant differences in animal numbers during the irrigation and non-irrigation seasons.

Table 28: Non-irrigation Season Dairy-related Parameters and FC Pollution – 1998

Sub-basin #	Dairy Acres (#)	Cows (#)	Heifer Repl. & Calves (#)	Total Animals (#)	Animals per Acre (#)	FC Geometric Mean Density (cfu/100 mL)	FC 90th Percentile Density (cfu/100 mL)
1&2	150	1,125	900	2,025	13.50	*	3,800
3	1,331	7,594	401	9,326	7.01	170	2,000
4	800	425	0	450	0.56	780	2,800
5	676	1,625	1,200	2,825	4.18	30	63
6	600	2,000	1,500	3,500	5.83	300	430
7	3,021	12,267	2,584	14,851	4.92	380	1,000

* Not enough sampling data available to calculate.

Table 29: Non-irrigation Season Dairy-related Parameters and FC Pollution – 2000

Sub-basin #	Dairy Acres (#)	Cows (#)	Heifer Repl. & Calves (#)	Total Animals (#)	Animals per Acre (#)	FC Geometric Mean Density (cfu/100 mL)	FC 90th Percentile Density (cfu/100 mL)
1&2	162	1,249	901	2,150	13.27	*	*
3	1,764	5,667	535	6,202	3.52	100	100
4	28	520	175	695	24.82	148	410
5	676	1,700	600	2,300	3.40	8	34
6	90	1,600	700	2,300	25.56	322	4,300
7	3,472	13,114	4,695	17,712	5.10	34	92

* Not enough sampling data available to calculate.

Multiple regression analyses of the 1998 and 2000 non-irrigation data versus both the sub-basin geometric mean and 90th percentile FC densities were then performed. No significant correlations were observed when comparing the dairy-related parameters to either FC geometric mean or 90th percentile densities for either the year 1999 or 2000.

Table 30 details the average daily discharge values throughout the sub-basins of the watershed during the non-irrigation season. A comparison of Table 22 with Table 30 vividly demonstrates the seasonality of agricultural drainage return flows, with the greatest flows always occurring during the irrigation season. During the non-irrigation season, the percent reduction of the 2000 sub-basin discharge flows, since 1992, have ranged from 48% (sub-basin #4) to 91% (sub-basin #3). The non-irrigation season watershed flows have averaged approximately 62% less than the respective irrigation season flows.

Table 30: Non-irrigation Season Average Daily Discharge (cfs) for Sub-basins – 1992 through 2000

% Reduction 1992 - 2000	Sub-basin #	RSBOJC 2000	RSBOJC 1999	RSBOJC 1998	RSBOJC 1997	Ecology 1995	SYCD 1992
*	1&2	*	*	5.8	*	*	2.1
91	3	0.5	0.4	0.5	0.4	*	5.5
48	4	3.3	3.4	3.5	3.9	*	6.3
62	5	2.3	2.1	2.1	*	*	6.0
68	6	1.0	1.1	1.0	1.1	*	3.1
52	7	2.9	3.6	2.7	3.7	*	6.0

* Not enough sampling data available to calculate.

Table 31 details the non-irrigation FC geometric mean densities found in the mainstem Granger Drain since 1992.

Table 31: Non-irrigation Season FC Geometric Mean Densities (cfu/100 mL) and % Reductions for Mainstem Granger Drain – 1992 through 2000

% Reduction 1992 - 2000	Sub-basin #	RSBOJC 2000	RSBOJC 1999	RSBOJC 1998	RSBOJC 1997	Ecology 1995	SYCD 1992
90	23	115	94	210	1,620	*	1,200
*	13	*	*	*	600	*	480
74	8/7.5	220	*	*	630	*	850
68	24	159	180	350	980	*	500

* Not enough sampling data available to calculate.

From Table 31, the 2000 non-irrigation season data indicates that FC geometric mean densities were consistently nearing their respective State water quality criterion of 100 cfu/100 mL, with site #23 nearly compliant with that criterion. The year-2000 FC geometric mean densities percent reductions have ranged from 68% to 90% since 1992. The data also indicated that for that same year (2000), FC densities were approximately 70% lower than their respective irrigation season FC densities. Table 31 also appears to indicate an unexpected increase in the FC geometric mean densities at sampling site #8/7.5, which is downstream of site #23 and upstream of site #24. The increase may be the result of the large FC pollution loading arising from sub-basins #5 and #6 (previously noted as abnormal), as well as may be representing FC pollution from sub-basin #9, which is located to the south side of the mainstem Granger Drain. Sub-basin #9 will be required to be monitored, as there has been no previous monitoring of that sub-basin.

From the above results, and in order to assure equal treatment of non-point sources throughout the entire Granger Drain watershed, BMP implementation activities should be intensified in sub-basins #5 and #6, and also initiated in sub-basin #9, if applicable monitoring results show them to be necessary. Some samples could also be collected at mainstem Granger Drain sampling site #13 so that any FC pollution from sub-basin #5 can then be separated from that attributable to sub-basin #6.

Table 32 details the non-irrigation season FC 90th percentile densities in the mainstem Granger Drain since 1992.

Table 32: Non-irrigation Season FC 90th Percentile Densities (cfu/100 mL) and % Reductions for Mainstem Granger Drain – 1992 through 2000

% Reduction	Sub-basin	RSBOJC				Ecology	SYCD
1992 - 2000	#	2000	1999	1998	1997	1995	1992
93	23	420	280	690	3,500	*	7,000
*	13	*	*	*	5,300	*	2,200
83	8/7.5	360	*	*	5,700	*	5,100
86	24	320	530	2,000	1,800	*	2,200

* Not enough sampling data available to calculate.

From the information provided in Table 32, the year-2000 FC 90th percentile densities during the non-irrigation season have all been reduced by over 80% since 1992 and are approximately 75% lower than their respective irrigation season FC densities. It is important to note, that all of the latest 90th percentile FC densities collected in the mainstem Granger Drain, during the non-irrigation season, are already in compliance with the *Granger Drain Fecal Coliform Bacteria TMDL*'s interim target of 510 cfu/100 mL.

3. <u>FC vs. Suspended Sediment and Turbidity</u>

Earlier in this assessment/evaluation, it was stated that FC bacteria have been documented in the scientific literature to adsorb to fine suspended sediment particles. This occurs in a fashion similar to other known hydrophobic parameters, such as organochloride pesticides (i.e. DDT). This FC hydrophobicity is the result of a combination of ionic interactions, which allows the formation of ionic bridges to suspended sediment, as well as the physical formation of sticky lipopolysaccharides on the outer cell walls of FC bacteria. Baudart et al. (2000) noted that: "Bacterial loads during storm events…were associated with small clay particles…and were characterized by a large diversity of [bacterial] species". And Crane et al. (1983) stated that: "Once manure is applied to the land it becomes a potential non-point source of pollution from the agricultural sector."

Figure 8 shows the results of the year-round total suspended solids (TSS) monitoring values (analogous to suspended sediment) collected by the RSBOJC throughout the mainstem Granger Drain from 1997 through 2000 (n = 211), which indicated a highly significant but moderate ($p = <0.00001$, $r^2 = 0.4031$, $r = 0.6349$) correlation with FC densities.

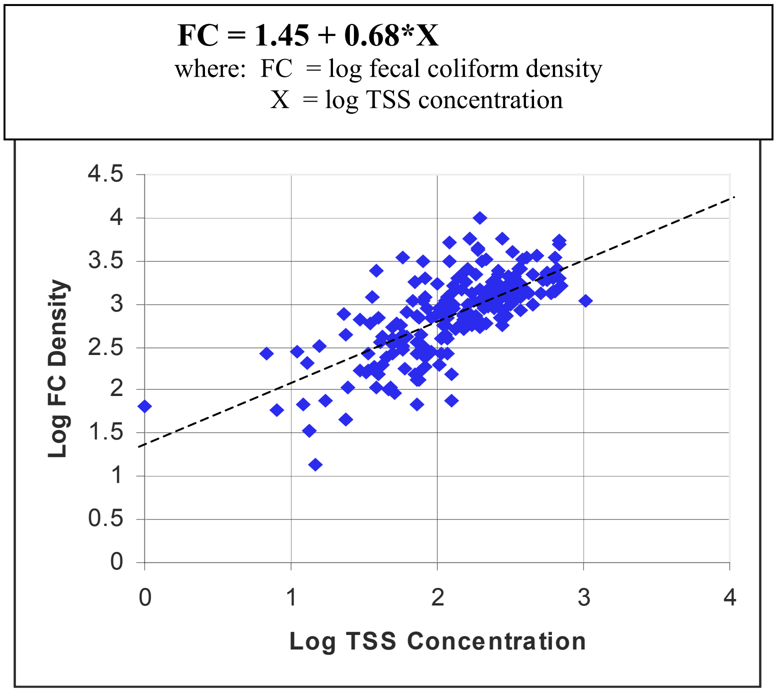

Figure 8

Log FC Densities vs. Log TSS Concentrations in Mainstem Granger Drain (1997-2000)

The highly significant positive correlation between FC densities and TSS concentrations observed in Figure 8 is not entirely unexpected as it was hypothesized by this assessment/evaluation to occur due to the strong adsorbance of FC bacteria to sediment particles, mentioned above. Similarly, the RSBOJC also hypothesized that: "A direct relationship is expected between flow and concentration during the irrigation season for TSS, turbidity, FC and TP.", which was written in its *Roza-Sunnyside Board of Joint Control Water Quality Monitoring Plan* dated April 7, 1997.

Since turbidity has previously been correlated to TSS (Ecology, 1997) it was also analyzed in this assessment/evaluation for a potential correlation to FC pollution in the mainstem Granger Drain. Figure 9, below, shows the results of analysis of turbidity vs. FC density data ($n = 211$) throughout the mainstem Granger Drain indicated another highly significant but moderate ($p < 0.00001$, $r^2 = 0.4481$, $r = 0.6694$) correlation.

FC = 1.51 + 0.86*X
where: FC = log fecal coliform density
X = log turbidity value

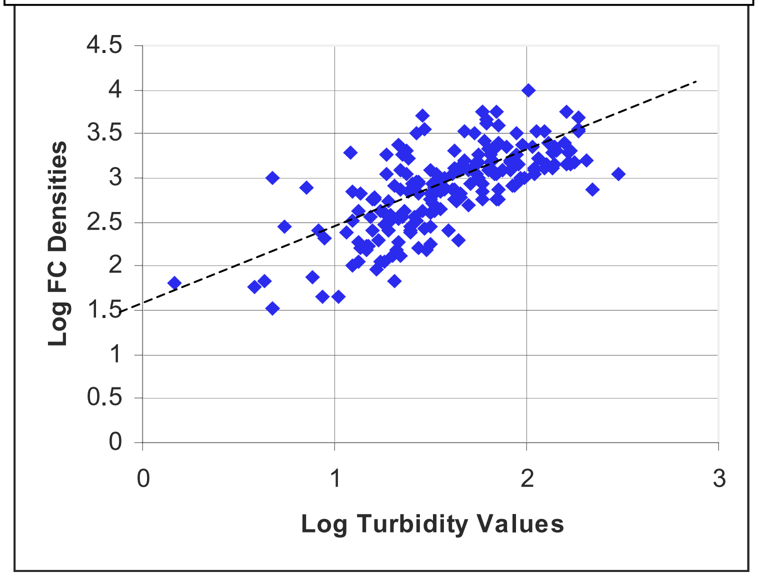

Figure 9

Log FC Densities vs. Log Turbidity Values in Mainstem Granger Drain (1997-2000)

This correlation is utilized for calculating an interim FC 90th percentile density that corresponds to the 25 NTU interim turbidity target (90th percentile) contained in Ecology's LYRSS TMDL and which is applicable commencing with the year 2007 irrigation season. The following FC interim target will be included into the *Granger Drain Fecal Coliform Bacteria TMDL*: a 90th percentile of 510 cfu/100 mL.

In support the interim target, an analysis of the historical FC densities indicated that the FC 90th percentile densities (episodes of worst-case pollution) have always been the most difficult to meet the FC water quality standard. The State's Class A FC standard are two-tiered, which means that both tiers (geometric mean and 90th percentile) must be met at the same time. Since the 90th percentile tier has typically been the most difficult to achieve, there is sufficient rationale for using only a 90th percentile interim FC target in the *Granger Drain Fecal Coliform Bacteria TMDL* as a step-wise progression in order to ultimately achieve compliance with the State's Class A FC water quality standards.

4. SVID and RID Canal Water

During 1998, 1999 and 2000, the RSBOJC monitored the water quality in both the SVID and RID irrigation water supply canals. Table 33 presents the sampling locations utilized during the monitoring of the Granger Drain watershed's two major irrigation water supply canals.

Table 33: Sampling Locations for SVID and RID Canals

Canal Section	SVID Canal Sampling Location	RID Canal Sampling Location
Upstream	at footbridge just downstream from Sunnyside Diversion Dam on Yakima River immediately below the City of Union Gap (CM 0.60)	at community of Pomona along the Yakima River near the entrance to the Yakima Canyon (CM 4.95)
Entrance	at Beam Road (CM 24.73)	at Beam Road (CM 44.10)
Downstream	at Van Belle Road (CM 37.00)	at Ray Road (CM 59.10)

The 1995 SVID and RID irrigation water supply canal monitoring data indicated that the *downstream* water in both canals would best represent the water quality pollution derived from the Granger Drain watershed. Therefore, tracking the geometric mean and 90th percentile FC densities, from 1995 through 2000, should be indicative of the results of BMP implementation upland of those irrigation canals. Table 34 details the SVID canal's downstream FC density data and statistics from 1995 through the year 2000, during the irrigation seasons.

Table 34: Downstream SVID Canal Water FC (cfu/100 mL) Ranked Data – 1995 through 2000

	1995	1998	1999	2000
	790	1400	510	340
	490	340	250	140
	330	330	240	140
	330	260	180	120
	240	260	180	120
	180	250	160	100
	170	230	150	100
	170	220	150	96
	140	210	130	93
	130	200	77	64
	79	130	68	64
	23	37	11	39
	13	-	-	-
	7.8	-	-	-
Geometric Mean	123	234	131	103
90th Percentile	490	340	250	140

From Table 34, it was determined that the FC densities in the SVID canal water at the downstream end of its passage through the watershed have been improving greatly over time. The greatest improvement has been with the FC 90th percentile densities, which have decreased 71% since 1995. The FC geometric means have only decreased 14% during that same time.

All such improvements, especially those associated with the episodes of worst-case FC pollution, are suspected to be representative of extensive BMP implementation throughout the upland watershed areas concerning manure management and suspended sediment runoff. It should be noted that the year-2000 geometric mean and 90th percentile FC densities are just about achieving complete compliance with the State's Class A FC water quality standards. Table 35 details the RID canal's downstream FC density data and statistics from 1995 through the year 2000, during the irrigation seasons.

Table 35: Downstream RID Canal Water FC (cfu/100 mL) Ranked Data – 1995 through 2000

	1995	1998	1999	2000
	240	260	220	170
	79	190	170	110
	79	130	150	97
	79	120	140	65
	70	120	130	60
	49	110	110	50
	49	92	110	45
	49	85	76	33
	33	66	50	29
	33	51	49	23
	33	21	46	18
	31	19	10	17
	11	-	-	-
	1.8	-	-	-
Geometric Mean	39	83	83	47
90th Percentile	79	190	170	110

From Table 35, it was determined that there has been no significant improvement with the FC densities in the RID canal water at the downstream end of the watershed. This is not unexpected, since the RID was previously found to have minimal discharges from upland farmlands; while, the SVID is known to have various discharges. It should be noted that the geometric mean and 90th percentile FC densities at the downstream end of the RID canal's route through the Granger Drain watershed have been consistently in compliance with the State's Class A FC water quality standards throughout all of the years from 1995 to 2000.

Some additional specific findings are that, during 1998, the *downstream* section of the SVID canal was found to contain significantly (ANOVA, $p = 0.0038$) greater FC pollution than either the *upstream* or *entrance* sections of the canal. Since the *upstream* and *entrance* sections indicated no significant difference between them concerning FC densities, subsequent sampling (1999 and 2000) was conducted only at the *upstream* and *downstream* sections. During 1999, the *downstream* section of the SVID canal indicated no significant (t-test, $p = 0.1605$) difference in FC densities from the *entrance* section.

However, the 2000 data indicated once again that the *downstream* section contained significantly (t-test, p = 0.0217) greater FC densities from the *upstream* section. During 1998, there was found no significant (ANOVA, p = 0.2820) difference in FC pollution between the *upstream*, *entrance* and *downstream* sections of the RID canal. Since the *upstream* and *entrance* sections indicated no significant difference between them concerning FC densities, subsequent sampling (1999 and 2000) was conducted only at the *upstream* and *downstream* sections. During 1999 and 2000, the *downstream* section of the RID canal indicated no significant (t-tests, p = 0.0722 and p = 0.1052, respectively) difference in FC densities from the *upstream* section. This finding is similar to all previous comparisons noted in this assessment/evaluation concerning the RID canal water quality.

1999 USGS Bacterial Synoptic Sampling

The USGS conducted bacterial synoptic sampling throughout the Yakima River Basin from August 2-5, 1999. The data is presented in Appendix D. Table 36 details the maximum densities, from lowest to highest, of FC bacteria determined from analysis of that synoptic sampling.

Table 36: Maximum FC Densities (cfu/100 mL) per Yakima River Basin Waterbody – 1999

Location	FC
Yakima River at Cle Elum	3
Satus Creek at Wilson Charlie	3
Pacific P&L	17
Naches River	31
Yakima River above Ahtanum Creek	55
Yakima River at Umtanum	59
Umtanum Creek	92
Satus Creek below Dry Creek	100
Yakima River at River Mile 72	117*
Yakima River at Kiona	131*
Satus Creek at Mouth	140*
Snipes Creek	210*
Cherry Creek	260*
Sub-Drain #35	350*
Ahtanum Creek at Union Gap	370*
Marion Drain	430*
Toppenish Creek	450*
Spring Creek	580*
Wide Hollow Creek	600*
Wilson Creek	650*
South Drain #1	720*
East Toppenish Drain	840*
Sulphur Creek	1,400*
Moxee Drain	1,760*
Granger Drain	1,950*

* FC density in excess of the State's Class A water quality standards.

Analysis of Table 36 indicates a significant increasing trend in FC densities when progressing downstream in the Yakima River. Specifically, the FC densities started at 3 cfu/100 mL near Cle Elum and increased to 131 cfu/100 mL at Kiona. From the above data it is important to note that natural FC densities were still below 25 cfu/100 mL, as first noted with the 1988 USGS synoptic sampling. Also, agriculture drains have higher FC densities than their source water (Yakima River) with the Granger Drain having the highest density. That is one of the reasons for conducting the *Granger Drain Fecal Coliform Bacteria TMDL.*

2000 USGS/Ecology Bacterial Synoptic Sampling

The USGS, with assistance from Ecology, conducted water quality synoptic sampling throughout the Yakima River Basin during July (irrigation season) and October-November (non-irrigation season) of the year 2000. The results of FC bacterial analyses of the samples are detailed in Appendix E.

1. Subsurface vs. Surface Drainage System FC Pollution

   Analyses of the 2000 USGS data (Appendix E) were conducted to determine what, if any, differences in FC densities were present between subsurface and surface drainage systems. The largest individual FC density collected during the irrigation and the non-irrigation seasons (460,000 cfu/100 mL and 12,000 cfu/100 mL, respectively) were collected from subsurface drainage systems. In general, the subsurface drainage systems had highly significant (t-test, $p = 0.0023$) greater FC densities when compared to the surface drainage systems.

   During the irrigation season only, the subsurface drainage systems again contained highly significant (t-test, $p = 0.0007$) greater FC densities than the surface drainage systems. However, during the non-irrigation season there was determined no significant (t-test, $p = 0.6156$) difference between the subsurface and surface drainage system's FC densities. When comparing only the subsurface FC densities, there was observed significantly (t-test, $p = 0.0189$) greater FC densities during the irrigation season than during the non-irrigation season. In fact, the only subsurface drainage sampled in the Granger Drain watershed (DR-2 near the Outlook Fire Station) showed 1,100 cfu/100 mL during the irrigation season, but only 6 cfu/100 mL during the non-irrigation season.

   All of the above results are consistent with and support this assessment/evaluation's hypothesis that a second principal transport mechanism of FC pollution into the mainstem Granger Drain is through subsurface drainage systems. The finding that, during the irrigation season, greater FC densities are found in subsurface drainage systems is probably related to the fact that those systems typically by-pass BMPs implemented for reducing overland runoff. The SYCD described (in the June 28, 2001 TMDL Technical Advisory Workgroup meeting) the subsurface drainage systems in the Granger Drain watershed as old, in need of repair and known, at times, to allow the direct access of discharges from irrigated agriculture and AFOs through air vents and manholes. For that reason, the TMDL will require all subsurface drain systems to be located and mapped for future examination.

2. Analysis of General Locale Categories

In order to determine if any significant differences in FC pollution occur between the general locale categories, it was first necessary to list the sampling data from Appendix E more appropriately. Appendix F shows all of the 2000 USGS synoptic sampling data distributed into their respective general locale categories, minus the replicate and duplicate analyses. Next all of the values were transformed into logs so as to provide a normal distribution for subsequent statistical analysis. ANOVA statistical analysis determined that during the irrigation season, no significant ($p < 0.05$) differences in FC pollution existed between the general locale categories. (Note: since Umtanum only had one sample collected, no mean could be calculated, and thus that general locale had to be removed from the analysis.) However, it is expected that if more samples had been collected from Umtanum, such general locale would have contained significantly less FC pollution than the other general locales since it is in a nearly pristine area with no irrigated agriculture or AFOs.

However, during the non-irrigation season, there were several significant ($p < 0.05$) differences in FC pollution found between the general locales. (Note: as there was no sampled done of the Kiona, and both Umtanum and Buena-Zillah had only one sample collected, they all were removed from the analysis.) Table 37 details the results of the ANOVA statistical analysis between general locales. It is expected that had more samples been collected, the removed general locales of Umtanum and Buena-Zillah would have ranked in the bottom half of the table since animal agricultural is not so prevalent as in the other general locales.

Table 37: Non-irrigation Season FC Pollution per General Locale Categories – 2000

Order of FC Pollution	General Locale Categories	Geometric Mean FC Densities (cfu/100 mL)	90th Percentile FC Densities (cfu/100 mL)
Highest	Sulphur Creek	248	12,000
↓	Granger; Ahtanum-Wide Hollow	115; 291	570; 1,600
↓	Kittitas	48	4,300
↓	Moxee; Satus	29; 30	120; 50
Lowest	Spring-Snipes	11	66

The least non-irrigation season FC pollution was found within the Spring-Snipes general locale; whereas, the greatest FC pollution was found within the Sulphur Creek general locale. This finding is similar to that reported by the SYCD in their Bonneville Power Administration, Fish and Wildlife Program FY99 Proposal, which stated: "Sulphur Creek has been identified as one of the most polluted drains on the Yakima River for many years." The Granger Drain general locale, and the subject of this TMDL assessment/evaluation, was found to be the next highest FC-polluted general locale along with the Ahtanum-Wide Hollow general locale. Finally, Table 37 supports a prior

assumption of this assessment/evaluation: that the FC 90th percentile densities are typically the most difficult to meet the water quality standards.
It should be a priority of Ecology and all other agencies with jurisdiction in the above areas to first investigate if all point sources of FC pollution have been identified and permitted. Once that has been assured, then a detailed investigation of non-point sources of FC pollution should be conducted and BMPs implemented to prevent continued FC pollution of the receiving waters.

Conclusions

1968-1985 USGS Surface Water Quality Assessment

In general, the report indicated that increasing anthropogenic activities throughout the Yakima River Basin have resulted in corresponding increases of FC bacterial densities, with many of the areas with the largest FC pollution problems are sites downstream from agricultural-return flows or areas with large numbers of dairies. The Granger Drain is one of those agricultural return flows and the Yakima River at the drain's outfall contained a maximum of 3,100 cfu/100 mL. The areas with the least amount of anthropogenic activities (near Cle Elum) were typically characterized by FC densities of <25 cfu/100 mL.

1988 USGS Bacterial Synoptic Sampling

The greater the amount of agriculture in a basin, the greater the amount of associated bacterial pollution in the nearby receiving waters. Irrigation return drains collecting wastewater from agricultural lands that contain high concentrations of livestock had significant FC pollution problems. On the other hand, non-agricultural areas with wildlife demonstrated comparatively minor FC pollution (<25 cfu/100 mL). The principal transport mechanisms for irrigation return water from irrigated agriculture land-use areas were implicated to be both overland runoff and subsurface drainage. In support of that determination, the report made two important observations: (1) FC densities varied not only spatially but also temporally over days and even hours, and (2) the largest temporal variations were measured in waterways receiving irrigation return flow. An example of temporal variability was observed in the Sulphur Creek Wasteway (an agriculture drain near Sunnyside, WA) where the afternoon *E. coli* measurement was significantly greater than the morning measurement.

1992 SYCD Granger Drain Monitoring Study

Analysis of the annual data indicated that the confinement acreage of dairies and feedlots was significantly correlated to the geometric mean (average) FC pollution within the individual sub-basins of the Granger Drain watershed. That finding supports Ecology's historical view that the AFOs within the watershed represent a primary source of the FC pollution. However, it should be noted that sub-basin #6 had an annual (1991-92) FC geometric mean density of 3,100 cfu/100 mL even though it had no associated *dairy/feedlot acreage*. One explanation could be that the d*airy/feedlot acreage* land-use category considered only the actual animal confinement acreage but not the associated pastures and manure application sites. There may have also existed in sub-

basin #6 other potential non-point FC sources including, but not limited to: septic tanks and wildlife.
Because FC pollution throughout the Granger Drain watershed was greatest during the irrigation season, it is very important to separately analyze for any correlations to specific land-use types during that season. During the irrigation season, of the various specific land-use parameters tested, FC geometric mean densities were significantly correlated to *dairy/feedlot acreage* (positively), *corn/wheat acreage* (positively) and *alfalfa/pasture acreage* (negatively). A very similar correlation was obtained when comparing FC geometric mean densities to *dairy/feedlot acreage* (positively), *rill irrigation acreage* (positively), and *sprinkler irrigation acreage* (negatively).

The positive correlation found between FC geometric mean densities and *corn/wheat acreage* and *rill irrigation acreage* is assumed to be related to the fact that manure is applied extensively to corn crops, and that the predominant irrigation method of those crops is rill. Rill irrigation is also assumed to have the largest concentration of suspended sediment in its runoff of all the irrigation methods, and that such suspended sediment carries with it FC bacteria that are known to adsorb to it. The reasons for the negative correlation with *alfalfa/pasture acreage* and *sprinkler irrigation acreage* is assumed to be related to the differences in crop types and irrigation practices, which together are assumed to cause significantly less runoff of suspended sediment. During the non-irrigation season, no significant correlations between any agricultural land-use and the geometric mean or 90th percentile FC densities were found. Finally, the extreme difference between the irrigation and non-irrigation season FC densities illustrates the seasonality of such pollution.

It is hypothesized that the principal transport mechanism of FC pollution throughout the Granger Drain watershed is via overland runoff. Various other researchers have also identified runoff as the primary transport method of FC pollution. Doran and Linn (1979) stated that: "The bacteriological quality of runoff from pasture and rangeland often exceeds water quality standards.", and Crane et al. (1983) stated that: "As a rule, agricultural runoff exceeds recommended standards for recreational use of water." Finally, the USEPA (1997a) stated that: "In the agricultural areas, erosion [in the Yakima River Basin] from irrigation is the primary source of sediments being delivered to surface waters." Such a statement, in conjunction with the fact that FC bacteria adhere strongly to sediment particles (Crane et al., 1983), demonstrates the TMDL's basis for assuming that irrigated agriculture runoff is the principal transport mechanism of FC pollution to the watershed's surface waters.

The 1992 SYCD report also indicated that sub-surface drainage systems are capable of transporting FC pollution in the same densities as surface drainage systems, during both the irrigation and non-irrigation seasons. It is assumed that as manure and irrigation water are applied to the land, FC and other pollutants can be leached through soil into subsurface drainage systems, such as determined by various investigators including Wall et al. (1997). In addition, there can also be direct access of pollutants into subsurface drains through manholes, air vents, and illegal connections. Unfortunately, subsurface drainage systems circumvent the majority of the BMPs being implemented for controlling overland runoff and thus would need to have specialized BMPs (i.e., constructed wetlands) developed and implemented, if still found to be transporting excessive FC pollution.

1995 Ecology Fecal Coliform Monitoring

FC pollution throughout the Granger Drain watershed significantly improved from 1992 to 1995 (reduced by approximately 90%). The reduction is presumed to have been due to improved on-site manure/wastewater management at dairies, as well as the implementation of various BMPs for reducing suspended sediment in overland runoff. Unfortunately, even with the significant reduction in FC, the mainstem Granger Drain still exceeds the Class A FC water quality standards.

A detailed analysis of the monitoring data (irrigation season only) found no significant correlation between FC geometric mean densities and the various dairy-related parameters tested. However, there was observed a significant (5% level) correlation between 90th percentile FC pollution and the *# cows* per sub-basin. This appears to support the findings of the 1992 data, which also found *dairy/feedlot acreage* (another dairy-related parameter) to be significantly correlated with FC pollution, but to a greater degree. Interestingly, Truman et al. (1998) also discovered a significant correlation between dairies and FC pollution: "In comparing land-use relationships, the highest correlation [with FC] was indicated between dairy waste application fields [acreage] and milking herd density." Updated agricultural land-use data, when available, will need to be evaluated to consider potential correlations with parameters other than just dairy-related ones, such as irrigated agriculture.

The irrigation water contained in the SVID canal at the *downstream* end of it passage through the Granger Drain watershed, during 1995, contained significantly (5% level) more FC pollution than that of the *downstream* section of the RID canal. Such pollution was found to be originating from FC pollution transported in upland agricultural drainage return water that, during the irrigation season, is discharged into the SVID canal and not to the mainstem Granger Drain. The upland areas are supplied with irrigation water by the RID and Outlook canals and contain numerous dairy animals and various acres of manured agricultural fields.

1997-2000 RSBOJC Fecal Coliform Monitoring

The 1997-2000 FC monitoring data indicated a very strong seasonality of FC pollution throughout the Granger Drain watershed, being significantly greater during the irrigation season. FC densities were found to be significantly correlated to TSS concentrations and turbidity. A major reason for the correlation is due to the hydrophobicity of the FC bacteria and their resultant attachment to smaller particles (Baudart et al., 2000) that typically comprise the majority of suspended sediment. Specifically, Wallbrink et al. (1999) found that: "…the [rill-irrigation] runoff process selectively eroded and transported finer grains... (<2 μm) size."

In order to support the assumption that TSS concentrations and FC pollution in the Granger Drain are related, the separate irrigation and non-irrigation season data collected by the RSBOJC were analyzed. There was observed no significant difference between the season's pollution. Even though the Granger Drain watershed receives an average of 36 inches of irrigation water compared to the 7-9 inches of natural precipitation that typically occurs during the non-irrigation season, FC pollution still correlates well to concentrations of TSS throughout both seasons.

On-site operations at dairies, although previously (1992 and 1995) correlated with FC pollution during the irrigation seasons, have recently (1998 and 2000) been shown to have no such correlation. This shift probably reflects the industry's constantly improving manure management techniques, especially in light of the recent enactment of the State's *1998 Dairy Nutrient Management Act* and the industry's closer scrutiny by Ecology and third-party environmental groups. Even though FC pollution does not presently show a significant correlation with on-site dairy operations, the basic problem of FC pollution in the Granger Drain watershed is still hypothesized to be related to the manure through land application to irrigated agricultural lands. The TMDL will allow for further testing in order to determine, to the extent possible, the percentage of FC pollution pertaining to cows, humans, wildlife and other sources, as well as demonstrate the concentrations of FC leaving manure-applied fields vs. control fields. The SYCD is having DNA analyses of FC bacteria from the watershed's 2001 irrigation season performed at the University of Washington, which will be of great interest to everyone involved with the *Granger Drain Fecal Coliform Bacteria TMDL*.

To determine the correlation between agricultural land-uses and FC pollution, more recent information needs to be analyzed. The WSUCE recently compiled an agricultural land-use inventory for the year 1999. Previous data analyses suggest that the application of manure to irrigated agricultural lands and the associated runoff has caused severe FC pollution of the Granger Drain and the downstream Yakima River. In addition, both the 1999 and 2000 data indicate that *row crop acres* are significantly correlated with FC densities, which once more suggests that overland runoff from irrigated agriculture is a principal transport mechanism of FC pollution. In fact, the SYCD's 1982 South Yakima Model Implementation Plan (MIP) stated that: "The principle source of pollution resulting from farming practices was identified as suspended sediment in surface runoff." Since 1992, the implementation of BMPs for mitigating the effects of suspended sediment in agricultural runoff, as well as improved manure management at dairies, has resulted in the geometric mean and 90th percentile FC densities to decrease by 95% and 99%, respectively.

The large increases in FC densities at sampling point #8/7.5 on the mainstem Granger Drain compared to the upstream sampling point (#23) is of great concern to the overall success of the *Granger Drain Fecal Coliform Bacteria TMDL*. Although BMPs have been implemented throughout the watershed, it is suspected that they have been implemented to a much lesser degree, if at all, in sub-basin #9, which is located to the south side of Interstate 82 and has not been previously identified as a FC pollution source. It is suspected that significant FC pollution is derived from sub-basin #9 due to the AFOs located there. Sub-basin #9 has not been previously monitored due to various reasons but will now be required to be monitored to comply with the requirements of the *Granger Drain Fecal Coliform Bacteria TMDL*.

The downstream SVID canal contains significantly more FC pollution than its upstream section. The pollution is probably derived from direct discharges of irrigation return water emptying back into the SVID canal during the irrigation season as it passes through the Granger Drain watershed. However, the most recent monitoring data (2000) indicated that the *downstream* FC pollution within the SVID canal has improved significantly from 1998, which probably is the result of BMP implementation for reducing suspended sediment. Unfortunately, the *downstream* section still contains significantly (t-test, $p = 0.0217$) more FC pollution than its *upstream* section and remains in non-compliance with the State's Class A water quality standards.

On the other hand, the FC densities within the RID canal water were very consistent during its passage through the Granger Drain watershed during the years of 1998-2000. The background FC densities for the SVID canal water are: a geometric mean of 103 cfu/100 mL and a 90th percentile of 140 cfu/100 mL. Those for the RID canal water are: a geometric mean of 47 cfu/100 mL and a 90th percentile of 110 cfu/100 mL. The water within the irrigation supply canals will be required by the *Granger Drain Fecal Coliform Bacteria TMDL* to continue to comply with the State's Class A FC water quality standards.

1999 USGS Bacterial Synoptic Sampling

Although the 1999 USGS synoptic sampling data collected throughout the Yakima River Basin was temporally limited (synoptic), it indicated that areas of least anthropogenic activity contained the least FC pollution (<25 cfu/100 mL). This is similar to the Muddy Creek Fecal Coliform TMDL in Virginia (1999) that also found "… a fecal coliform concentration of 30 cfu/100 mL applicable to pristine areas". Whereas, concentrated agricultural land-use in the Granger Drain watershed corresponded to a significant increase of FC pollution (>1,000 cfu/100 mL). On the other hand, the outfall of the Granger Drain watershed, represents significant anthropogenic conditions and would be expected to show a tremendous increase in FC densities over that found with natural background conditions. The results of the 1999 synoptic sampling data supported similar findings described by the July 1988 USGS synoptic sampling.

2000 USGS/Ecology Bacterial Synoptic Sampling

The significantly greater FC concentrations found in the subsurface drainage systems tested as compared to the surface drainage of the Yakima River Basin during the irrigation season, support the hypothesis that such systems represent a significant transport mechanism of FC pollution. In fact, the largest FC densities sampled during both the irrigation and non-irrigation seasons were collected from subsurface drainage systems. The scientific literature indicates that the use of subsurface drainage systems is: "…frequently accompanied by detrimental environmental impacts as natural hydrological pathways and hydrochemical processes are modified." (Dils and Heathwaite, 1999). Laubel et al. (1999) found that "…the presence of macropores can enhance the mobility of [hydrophobic] particles [such as FC bacteria] because adsorption, sedimentation, and sieving is less pronounced …" This information supports the TMDL's hypothesis that subsurface drainage systems pose a serious potential for transporting FC pollution in the Granger Drain watershed.

Accordingly, the *Granger Drain Fecal Coliform Bacteria TMDL* considers subsurface drainage systems to be a collection of non-point sources, even when ultimately discharging through a discrete outfall. This assessment/evaluation will require that the local agencies responsible for management of surface and subsurface drainage systems to locate and map all such subsurface drainage outfalls and to monitor those that discharge directly into the mainstem Granger Drain to locate the sub-basins of greatest FC pollution. If such outfalls are found to exceed the State's Class A FC water quality standards, then BMP implementation will be required to mitigate the discharge of excessive FC densities.

In order to ultimately comply with the State's Class A FC water quality standards (after the 2012 irrigation season), such subsurface drainage outfalls must first comply with the TMDL's interim FC target of a 90^{th} percentile of 510 cfu/100 mL commencing with the 2007 irrigation season.

An analysis of the FC densities sampled from surface water in various general locales throughout the Yakima River Basin determined that FC pollution appears to increase proportionately to the amount of agricultural activity within a general locale (a conclusion also made by the 1988 and 1999 USGS synoptic sampling reports). Statistical analysis of the irrigation season data showed no significant ($p < 0.05$) difference between the general locales. Whereas, analysis of the non-irrigation season indicated a definite hierarchy of FC pollution between the general locales. The Sulphur Creek general locale (an area with concentrated agriculture, both irrigated and industrial (dairies and feedlots), was determined to have the greatest FC pollution densities. The Granger Drain watershed was determined to be similar to the Ahtanum-Wide Hollow general locale with respect to FC pollution, both of which followed Sulphur Creek as the next most FC polluted general locales during the non-irrigation season.

TMDL Analysis

CRITICAL CONDITION DISCUSSION

After analysis of the historical water quality monitoring data, the critical conditions for FC pollution throughout the Granger Drain watershed are as follows:

- Presently, FC concentrations in the mainstem Granger Drain significantly exceed the State's two-tiered FC Class A standard during both the critical condition/irrigation season (April through October) and, to a much lesser extent, during the non-irrigation season (November through March). However, it is expected that the majority of the BMPs cannot be implemented on a strictly seasonal basis and so the *Granger Drain Fecal Coliform Bacteria TMDL* shall be required throughout the entire year.

- Overland runoff from manured irrigated agriculture, especially rill irrigation, is hypothesized to be a principal transport mechanism and source of FC pollution throughout the Granger Drain watershed. Not only is FC pollution more predominant during the irrigation season, there was also found a highly significant but moderate correlation between FC densities and TSS concentrations in the mainstem Granger Drain.

- Subsurface drainage is hypothesized to be another principal transport mechanism of FC pollution. Such drainage, although relatively deep and not "tile" drainage, is present underneath a substantial portion of the Granger Drain watershed, including some dairy facilities. Although, typically thought to be difficult to pollute, historical records indicate that discharges of FC-polluted wastewater enter subsurface drainage systems through air vents, manholes and direct connections. The *Granger Drain Fecal Coliform Bacteria TMDL* will monitor the extent of FC pollution being transported through subsurface drainage systems and mitigate all significant FC sources.

- The points of compliance for the *Granger Drain Fecal Coliform Bacteria TMDL* will be all points in the mainstem Granger Drain, as well as all points in the SVID and RID irrigation water supply canals.

SETTING TMDL TARGETS FOR THE MAINSTEM GRANGER DRAIN

The State's Class A FC standard is composed of two tiers: a geometric mean of 100 cfu/100 mL, with no more than ten percent of the samples exceeding 200 cfu/100 mL (estimated by the ranking parameter of a 90th percentile). The water quality within the entire mainstem Granger Drain is presently not meeting either tier during the irrigation and non-irrigation seasons; however, during the year-2000 non-irrigation season, some sites are closely approaching that standard. Compliance during the irrigation season will obviously take longer since FC densities during that season are significantly greater than during the non-irrigation season. No seasonal implementation of BMPs for the *Granger Drain Fecal Coliform Bacteria TMDL* will be considered, as the typically implemented BMPs cannot be easily removed once installed (i.e. sedimentation ponds). Therefore, BMP implementation shall be year-round.

In order to comply with a specific standard, the variability of data obtained from sampling must first be examined. Ott (1994) proposed a **statistical theory of roll-back** (STR) that uses the statistical characteristics of a set of water quality data to estimate the distribution of future data after BMPs are applied to pollution sources. The STR also estimates a data set's likelihood to comply with water quality standards by estimating the most stringent tier: either the geometric mean or the 90th percentile densities. The STR relies on basic dispersion and dilution assumptions and their effect on the distribution of chemical or bacteria monitoring results at a site downstream of the potential sources. In the case of the *Granger Drain Fecal Coliform Bacteria TMDL*, compliance with the State's Class A FC standard is contingent on the most stringent component of that two-tiered standard.

Using the formulas provided by Ott, alternative FC targets were calculated for several sets of annualized data. Table 38 presents the results of using the STR to predict an alternative geometric mean that would assure compliance with the State's Class A FC standards. For each set of data analyzed, the STR calculations indicate that the 90th percentile FC density of 200 cfu/100 mL will be the most difficult to meet. Therefore, using only the year-2000 data, the STR calculations estimated an alternative geometric mean FC density of 73.8 cfu/100 mL that should be met, rather than the State standard of 100 cfu/100 mL, in order to assure compliance with the more difficult 90th percentile standard.

Table 38: FC STR Analyses of Irrigation Season Data – 1997 through 2000

Year of Record	Monitoring Agency	N	Geometric Mean	90th Percentile	Geometric Mean Rollback	90th Percentile Rollback	Alternative Geometric Mean
1997	RSBOJC	38	1,530	4,000	0.065	0.050	76.5
1998	RSBOJC	48	960	2,200	0.104	0.091	87.3
1999	RSBOJC	27	1,260	3,300	0.079	0.061	76.4
2000	RSBOJC	43	590	1,600	0.169	0.125	73.8

Different periods of record, sampling frequencies, analytical methods and BMP implementation strategies can influence the resulting distribution of FC concentrations and its statistical characteristics. Accordingly, this assessment/evaluation determined that using only the 2000 irrigation season data would be most representative of present-day critical conditions within the mainstem Granger Drain. The year-2000 irrigation season data also indicated a significant improvement over water quality data from previous years. Therefore, combining the 2000-year data with earlier year(s) would not be beneficial nor representative.

To not be more stringent than the requirements of the LYRRSS TMDL, the EPA (Region 10) suggested using the targets and timeline of that TMDL for determining the *Granger Drain Fecal Coliform Bacteria TMDL*'s initial targets and timelines. The reasoning is that there was previously documented a significant correlation between suspended sediment concentrations and FC densities, as well as a similarity in BMPs utilized for controlling both of those pollutant parameters. If after reaching the final 2012 TMDL target, the FC densities are not in compliance with the State's Class A FC water quality standard, then the most recent data will need to be re-examined by the STR methodology.

The *Granger Drain Fecal Coliform Bacteria TMDL* will contain a two-step process to ultimately meet the Class A FC standards. Commencing with the 2007 irrigation season, the TMDL compliance points (all points in the mainstem Granger Drain, as well as all points in the SVID and RID canals) shall be required to meet a FC 90th percentile target of 510 cfu/100 mL. Then, commencing with the 2012 irrigation season, the TMDL compliance points shall be required to meet the two-tiered Class A FC standard (geometric mean of 100 cfu/100 mL and a 90th percentile of 200 cfu/100 mL). The dates and target FC densities included in the TMDL were specifically selected to coordinate with the targets and timelines required by Ecology's *Lower Yakima River Suspended Sediment TMDL*.

LOADING CAPACITY

Loading capacity is defined as the maximum amount of a pollutant that a waterbody can receive and still meet applicable water quality standards. In the case of the *Granger Drain Fecal Coliform Bacteria TMDL*, the loading capacity for FC bacteria in the mainstem Granger Drain varies greatly with flow, which in turn is dependent on applied irrigation water. The TMDL will not establish a specific loading capacity per se, but rather will achieve similar results by strict regulation of point and non-point sources within the Granger Drain watershed allowing ultimate compliance with the State's Class A FC standard.

Therefore, the *Granger Drain Fecal Coliform TMDL* will use a different measure than "*daily loads*" to fulfill the requirements of Section 303(d). Instead, the TMDL is expressed in terms of FC density as allowed under EPA regulations [defined as "*other appropriate measures*" in 40 CFR §130.2(I)]. In such case, a density measure is appropriate due to the consistent relationship between the FC water quality standard and the receiving water quality for all receiving water flow rates. Therefore, the use of a flow rate to calculate "*daily loads*" is unnecessary. In addition, a loading capacity could require unnecessary TMDL and permit modifications as the agricultural land-uses change throughout the Granger Drain watershed.

LOAD AND WASTELOAD ALLOCATIONS

The Granger Drain watershed contains no municipal point sources of pollution, however, there are several industrial/commercial point sources. These consist of fourteen NPDES permitted CAFOs (dairies). All of the permitted CAFOs shall be allotted a wasteload allocation of zero, as they are not allowed to have any discharges, except under extreme climatic conditions: >25-year, 24-hour storm event (RCW 90.64.010(18)(a)(i)).

On the other hand, overland runoff and subsurface drainage systems throughout the watershed collect water from non-point sources of pollution and then discharge directly into sub-basin tributaries or the mainstem Granger Drain, which are all waters of the State. Because both of these methods transport excessive amounts of the FC pollution as seen with the 1992 and 2000 data, all points in the mainstem Granger Drain, as well as all points in the SVID and RID irrigation water suppy canals, will be given interim and final load allocations. The interim FC load allocation shall be 510 cfu/100 mL (90^{th} percentile) and becomes effective commencing with the 2007 irrigation season. Then, commencing with the 2012 irrigation season, a final FC load allocation equal to a geometric mean of 100 cfu/100 mL and a 90^{th} percentile of 200 cfu/100mL (Class A water quality standards) will become effective.

Other types of non-point sources of FC pollution such as AFOs and septic tanks, will be given a load allocation of zero because they are required to have no discharge of pollutants at any time to the waters of the State, including the mainstem Granger Drain.

REASONABLE ASSURANCE

The ultimate goal of the *Granger Drain Fecal Coliform Bacteria TMDL* is to meet the State's Class A water quality standards commencing with the 2012 irrigation season. That FC goal will be required to be maintained once compliance is achieved. Ecology is reasonably assured that the TMDL goal will be met because:

- BMP implementation for mitigating the runoff of suspended sediment (in compliance with the *Lower Yakima River Suspended Sediment TMDL*), as well as improvements in manure management (in compliance with the *Washington Dairy Nutrient Management Act of 1998*), have reduced TSS in the Granger Drain, from 1997-2000, by 85% and FC densities by 66%. Therefore, the *Granger Drain Fecal Coliform Bacteria TMDL* will require full compliance with the requirements detailed in the above two administrative documents in order to obtain the greatest FC reduction possible with the least amount of new capital expense.

- Land-owners, farmers, operators and public agencies have all been working extremely well in cooperation to comply with the requirements of the above two administrative documents. Thus, intuitively, many of the local BMP implementation activities that would have been required for *Granger Drain Fecal Coliform Bacteria TMDL* are already in place, or are being installed, throughout the Granger Drain watershed. Continued implementation of these BMPs should reasonably assure that the goals of the TMDL will be met.

- The use of a 90^{th} percentile interim FC target of 510 cfu/100 mL commencing with the 2007 irrigation season that correlates exactly with the 90^{th} percentile 25 NTU turbidity target and timeline of the LYRSS TMDL also gives reasonable assurance. All points in the mainstem Granger Drain and the SVID and RID irrigation water supply canals will be required to comply with the above targets. Analysis of actual 1992-2000 data projects that the interim target should be achieved in 2005, so the addition of two years (2007) should reasonably assure compliance with the goals of the *Granger Drain Fecal Coliform Bacteria TMDL* and allow for any unforeseen problems to be mitigated.

- The final *Granger Drain Fecal Coliform Bacteria TMDL* goal of meeting the State's Class A FC water quality standard commencing with the 2012 irrigation season should also be reasonably assured, since actual data from 1992-2000 has projected that such goal should actually be achieved in 2010. The additional two years (2012) to coordinate with the *Lower Yakima River Suspended Sediment TMDL* timeline should reasonably assure compliance with the goals of the *Granger Drain Fecal Coliform Bacteria TMDL*.

- The Granger Drain watershed has numerous smaller AFOs and "hobby farms". The FC pollution from such sites, when combined, may become more and more significant as suspended sediment concentrations in irrigated agriculture runoff is reduced. These non-point sources will be encouraged, through public outreach and technical assistance, to develop and implement nutrient management plans, as well as to fence stream-banks to prevent direct access by livestock to surface waters within the watershed. The TMDL implementation plan includes a requirement for the dissemination of information in both Spanish and English to all AFOs and "hobby farms[8]" within the watershed.

- The community of Outlook is reported to have numerous (possibly 100) failing and non-functioning on-site septic systems. These systems are thought to presently have a negative impact on the mainstem Granger Drain as well as on the ground water of the area. The city of Sunnyside will have planned a sewer connection project during its 2003-2004 fiscal year, but any actual connection activities will need to be done by Yakima County. Therefore, this TMDL will require that Ecology actively help the County in obtaining funding for the sewering of the community by the end of 2006.

- Whenever applicable BMPs are not being implemented and Ecology has reason to believe that individual sites or facilities are causing pollution in violation of RCW 90.48.080, Ecology may pursue orders, directives, permits, or civil or criminal sanctions to gain compliance with the State's water quality standards (WAC 173-201A-160).

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[8] Hobby farms are facilities that are operated on a part-time basis with off-farm income being the principal income for the owner/operator. Such farms typically have only a few animals and very little cropland, but vary have several acres of pasture. Such facilities can have any combination of various types of animals (i.e., horses, cattle, sheep, llamas, goats). Any animal facility or farm operated commercially is not considered a "hobby farm".

MARGIN OF SAFETY

A requirement of this assessment/evaluation is a discussion of the margin of safety (MOS) to account for uncertainty in the calculated targets and recommendations. The MOS can be placed either implicitly in the assumptions, or explicitly as a separate load allocation or an additional target component. The *Granger Drain Fecal Coliform Bacteria TMDL* contain the following implicit MOS factors:

- Given the correlation between FC and TSS, compliance with the estimated LYRSS TMDL final TSS concentration of 7 mg/L will significantly overshoot the final FC target of the *Granger Drain Fecal Coliform bacteria TMDL* (81 vs. 200 cfu/100 mL). This represents significant MOS;

- If the final target or schedule in the LYRSS TMDL are accelerated and/or become more pristine, the likely sooner achievement of the *Granger Drain Fecal Coliform Bacteria TMDL* provides additional MOS; and

- The two-year lag time between the projected and actual FC targets allows sufficient time for correcting any problems that might arise during BMP implementation of the TMDL. This also provides additional MOS.

TMDL ASSESSMENT/EVALUATION SUMMARY

FC pollution within the Granger Drain watershed was historically attributed to the concentrations of numerous livestock and AFOs located throughout that watershed. Early data (1992) indicated a significant positive correlation between FC densities to *dairy/feedlot acreage*, which support the historical assumption. However, there was also a significant correlation between FC densities and *corn/wheat acreage* and *rill irrigation acreage*, which suggested that specific crops and irrigation methods might also be related to such pollution. The 1995 data indicated a positive correlation between a dairy-related parameter (# cows) and episodes of greatest (90^{th} percentile) FC pollution. While, still later data from 1998 and 2000 indicated that on-site diary parameters were not significantly correlated to FC pollution, whereas, *row crop acreage* was found to be extremely correlated.

The progressive decrease in the correlation between dairy-related parameters and FC pollution throughout the Granger Drain watershed, since 1992, is probably the result of extensive and improved manure management at such sites. In addition, the loss of suspended sediment from irrigated agriculture (principally rill irrigation) has been drastically reduced through the implementation of the LYRSS TMDL. To support the hypothesis that FC pollution and irrigated agriculture (via suspended sediment runoff) are linked, it was determined that FC densities were always greatest during the irrigation season, as well as significantly correlated to TSS concentrations. Throughout the mainstem Granger Drain from 1997-2000, an 85% decrease in TSS was directly associated with a 66% decrease in FC densities. Until an updated set of land-use data is developed, additional verification of the above assumption cannot be made.
Since 1992, all of the above actions have resulted in greater than a 90% reduction in FC densities throughout the mainstem Granger Drain. Although there occurred an enormous reduction in FC

densities, such pollution still exceeds the State's Class A water quality standard. The watershed's FC pollution is still assumed to be principally attributable to the numerous and concentrated livestock in the watershed, but indirectly instead of directly. The watershed contains vast amounts of manure that need to be utilized at agronomic rates in association with BMPs, or otherwise appropriately managed. Manured croplands then receive 36 inches of irrigation water that, if not controlled, will wash sediment with attached FC bacteria into the mainstem Granger Drain.

This assessment/evaluation projects that compliance with the goals and timelines of Ecology's LYRSS TMDL and the *Washington Dairy Nutrient Management Act of 1998* will also reasonably assure compliance with the goals of the *Granger Drain Fecal Coliform Bacteria TMDL*. That TMDL will include a 90th percentile FC interim target of 510 cfu/100 mL to become effective commencing with the 2007 irrigation season. Later, the State's Class A FC standards must be met commencing with the 2012 irrigation season. The ultimate TSS goal of the LYRSS TMDL is a 90th percentile of 7 mg/L and corresponds to a FC 90th percentile density of 81 cfu/100 mL (using the equations presented in this assessment/evaluation). Since the *Granger Drain Fecal Coliform Bacteria TMDL* requires a final FC 90th percentile target of only 200 cfu/100 mL, compliance with the LYRSS TMDL is expected to assure compliance with the final FC target of the present TMDL.

However, if the 7 mg/L TSS goal is later changed, then a new corresponding FC 90th percentile density will need to be calculated using the latest water quality monitoring data. If the new corresponding final FC 90th percentile density is still less than 200 cfu/100 mL, then no modification to the *Granger Drain Fecal Coliform Bacteria TMDL* timeline will be needed. However, if the new final FC target in the LYRSS TMDL are delayed and/or allow more contamination, then the *Granger Drain Fecal Coliform Bacteria TMDL* becomes more of the driver for the BMPs in the watershed.

TMDL Schedule and Actions

SCHEDULE

The *Granger Drain Fecal Coliform Bacteria TMDL* process was initiated on July 1, 1999 with the commencement of extensive historical research of all relevant monitoring data. On February 22, 2001, the first meeting of the TMDL's Technical Advisory Workgroup was held, during which the first draft of the *Granger Drain Fecal Coliform Bacteria Assessment/Evaluation* was distributed. Subsequently there have been three more drafts, including this final draft. A public meeting/workshop was held on August 2, 2001 at the Roosevelt Elementary School in Granger, WA, wherein the TMDL was introduced to the general public and the public comment period was initiated. The public comment period ended on September 17, 2001. An EPA review of the draft submittal package will be completed in the first week of November, 2001. The completed final TMDL submittal package, including the Summary Implementation Strategy (SIS), is scheduled to be submitted to EPA for approval by December 1, 2001.
The *Granger Drain Fecal Coliform Bacteria TMDL* contains FC targets and an implementation schedule that were established to coordinate exactly with the those of the LYRSS TMDL. The

Granger Drain Fecal Coliform Bacteria TMDL implementation schedule includes an interim FC target of a 90th percentile of 510 cfu/100 mL commencing with the 2007 irrigation season, and a final target of the State's Class A FC water quality standard effective commencing with the 2012 irrigation season. The TMDL interim and final targets are required to be met at all points in the mainstem Granger Drain, as well as all points in the SVID and RID irrigation water supply canals.

The MOS associated with the TMDL reflects some of the uncertainty in the collection and interpretation of the data, but other sources and causes may also be identified. Monitoring every two years for the effectiveness of the BMPs in reducing FC pollution will provide a continuous means for evaluating the applicability of the goals and timelines of the TMDL, as well as for identifying new BMPs. If needed, adjustments to the TMDL targets and schedule, as well as other actions, will be conducted accordingly through the TMDL public process.

ACTIONS FOR REDUCING BACTERIAL SOURCE IMPACTS

The success of a TMDL is not in setting goals, but in actual compliance with them. The interim and final FC targets of the *Granger Drain Fecal Coliform Bacteria TMDL* are appropriately coordinated with the goals contained in the LYRSS TMDL, as BMP implementation for that TMDL has already resulted in significant reductions in FC pollution within the mainstem Granger Drain. This assessment/evaluation hypothesizes that the majority of FC pollution reaching that waterbody is via the transport mechanisms of overland runoff and subsurface drainage from irrigated agriculture, and due to animal manure applied to those sites.

Based on past monitoring data, this assessment/evaluation assumes that continued implementation of past types of BMPs for reducing suspended sediment pollution in overland runoff, especially in manured areas, will reasonably assure compliance with the interim and final FC targets of the *Granger Drain Fecal Coliform Bacteria TMDL*. The implementation of new types of FC-specific BMPs (i.e., constructed wetlands) is not presently being required since FC reductions to-date have been progressing and are projected to meet the TMDL targets and goals. However, experimentation with new types of BMPs should be conducted for potential use, especially those pertaining to subsurface drainage systems.

The Granger Drain watershed has already had a long history (10 years) of successful watershed pollution abatement activities. BMP implementation by dairy owners, agriculturists and local governmental agencies have resulted in greater than a 90% reduction of FC pollution since 1992. Continued cooperation of both the private and public sectors will be needed for the *Granger Drain Fecal Coliform Bacteria TMDL* to be successful. From Ecology's viewpoint, new types of FC-specific BMPs will only be required by the TMDL in the event that evaluations of the continued implementation of prior types of BMPs project non-compliance with the goals of the TMDL. Such evaluations will be made every two years and will be based on the latest available monitoring data.

Manure Management at Dairies

This assessment/evaluation determined that although some sub-basins within the Granger Drain watershed contain high densities of dairies, such on-site facilities do not presently (since 1998) correlate to high FC pollution in local surface waters. This change in trends is presumed to be the result of improved on-site manure management at the various dairy facilities in recent years. Additionally, the basic strategy for implementing a FC source control program on dairies has been through the *Washington Dairy Nutrient Management Act of 1998*. Such Act requires that all dairy farms be inspected by October 2000 and have a nutrient management plan approved by the SYCD by July 31, 2002. The plans must be fully implemented, following USDA NRSC standards, by December 31, 2003. The plans are required to address site-specific needs associated with the production, collection, handling, transfer, treatment, storage, and land application of agricultural wastes. The *Granger Drain Fecal Coliform Bacteria TMDL* shall require complete compliance with the *Washington Dairy Nutrient Management Act of 1998*.

Even though on-site dairy facilities have not recently been correlated with high FC densities in downstream surface waters, it is assumed that watershed's FC pollution problems are still associated with such facilities. The FC pollution is hypothesized to be coming from irrigated agricultural fields that have received manure applications. The FC bacteria are hypothesized as traveling via the principal transport mechanisms of overland runoff and subsurface drainage.

Overland Runoff Management

Ecology's LYRSS TMDL has proven to be very effective in helping reduce FC pollution within the mainstem Granger Drain. Specifically, from 1997-2000, an 85% decrease in TSS has helped to reduce FC densities by 67%. Therefore, the continued implementation of prior types of BMPs for controlling overland runoff of suspended sediment from irrigated agriculture within the Granger Drain watershed is considered a priority of the *Granger Drain Fecal Coliform Bacteria TMDL*.

Overland runoff from manured fields, under the control of a CAFO owner or operator and not in association with greater than a 25-year, 24-hour precipitation event, will be considered a violation of that CAFO's NPDES general permit. When such situation occurs elsewhere, it will be considered a violation of State law (Chapter 90.48 RCW) and may require that a discharge permit be obtained by the property owner/operator involved (AFOs). The implementation of other BMPs such as off-stream watering, buffer strips and livestock exclusion (streambank fencing) should also be promoted to prevent the direct access of livestock to surface waters of the Granger Drain watershed. The TMDL will advocate these last types of BMPs for use at all AFOs and "hobby farms" within the watershed through public outreach and technical assistance, as well as, the potential need to prepare and implement manure management plans.

Subsurface Drainage Management

In the 1992 SYCD report, discussed previously, similar FC densities were found in both subsurface and surface water drainage systems. During the irrigation season, FC densities up to

160,000 cfu/100 mL were sampled from the subsurface drainage system utilized as one of the report's principal sampling sites. In the year 2000, the USGS conducted a synoptic sampling of FC bacteria throughout the Yakima River Basin, including the Granger Drain watershed. From the data provided, it was found that subsurface drainage systems are a transport mechanism of significantly high FC densities. That synoptic data determined that the greatest FC densities found throughout the entire Yakima River Basin during both the irrigation and non-irrigation seasons (460,000 cfu/100 mL and 12,000 cfu/100 mL, respectively) were collected from subsurface drainage systems.

As a result of the above information, the *Granger Drain Fecal Coliform Bacteria TMDL* will require that all subsurface drainage systems and outfalls within the Granger Drain watershed be identified and mapped. Only those subsurface drainage outfalls discharging into the mainstem Granger Drain will need to be monitored for locating sub-basins of excessive FC pollution. If any subsurface drainage system indicates excessive pollution, additional upstream monitoring will be required in order to identify the sources of such FC pollution and BMPs will need to be implemented to mitigate those sources.

<u>Other Potential Sources of FC Pollution</u>

During the irrigation season, only a very minor portion of the FC pollution entering the mainstem Granger Drain is assumed to come from human waste, with the only known sources to be the non-functioning and/or malfunctioning septic tanks within the community of Outlook. During the non-irrigation season, however, the potential affects of non-functioning and/or malfunctioning septic tanks may tend to increase, as the principal FC source (irrigated agriculture) diminish. Even though the amount of human FC pollution may be minimal, the health risks are potentially high (i.e., human pathogens are more prevalent in human waste than in animal wastes). In fact, the Yakima Health District declared on November 19, 1999 the existence of a public emergency within the community of Outlook due to widespread septic system failure, which "…poses a serious and immediate threat to the environment, health and safety of the community." Ecology will be required by the *Granger Drain Fecal Coliform Bacteria TMDL* to actively help Yakima County obtain funding in order to sewer the community of Outlook by the end of 2006.

Wildlife is another potential source of FC pollution that is assumed to be very minor throughout the Granger Drain watershed. The 1988, 1999 and 2000 USGS synoptic samplings all indicated that the areas of least anthropogenic activities had FC densities far less than the State's Class A FC standard. In fact, such FC densities typically were below 25 cfu/100 mL. Additionally, the data presented in Table 2 illustrates that confined cows produce far more FC bacteria per individual than every other animal tested. So intuitively, there would need to be concentrated vast herds and/or flocks of wildlife in the Granger Drain watershed, throughout the entire year, in order to have an equivalent manure output as the watershed's estimated 40,000 dairy cows.

<u>MONITORING ACTIONS</u>

A vital requirement of the TMDL process is a monitoring plan, which allows the collection of direct evidence of target compliance and BMP effectiveness. It can also provide the data necessary to answer uncertainty issues identified in the TMDL, and to modify or adjust FC targets. Monitoring throughout the Granger Drain watershed, including the SVID and RID irrigation water supply canals, has been conducted year-round by the RSBOJC since 1997. That agency has monitored the surface drainage on a bi-weekly (every two weeks) basis during the irrigation season and on a monthly during the non-irrigation season.

For compliance with the *Granger Drain Fecal Coliform Bacteria TMDL*, additional monitoring will be required consisting of the mainstem Granger Drain downstream of Granger and spot checks of the subsurface drainage system outfalls discharging into the mainstem Granger Drain. If any subsurface drainage outfall is discharging FC densities in excess of the State's Class A water quality standards, then the sub-basin containing such subsurface drainage system will be required to be monitored extensively in order to locate all significant sources of FC pollution. Once identified, BMP implementation will be required to mitigate the applicable FC sources. Compliance with the TMDL interim and final target densities will be evaluated every two years and will be based on the past two years of available monitoring data.

IMPLEMENTATION ACTIONS

An SIS for the *Granger Drain Fecal Coliform Bacteria TMDL* has been formulated by Ecology in direct consultation with the technical advisory workgroup, which is composed of active participants including: the watershed's irrigation and conservation districts, the USGS, Yakima Valley Dairy Federation, Hop Growers of Washington, Yakama Nation, Yakima County and Washington State University Cooperative Extension. The finalized SIS will then become part of the submittal package for the EPA and will be reviewed under the public process. With many of the local activities (i.e., BMP implementation) already in place and significant reductions in FC pollution having already occurred, compliance with TMDL goals is reasonably assured.

Major Findings of this Assessment/Evaluation

1. As it passes through the Granger Drain watershed, the SVID irrigation water supply canal collects significant quantities of FC pollution from upland areas via discharges of their irrigation return water with FC pollution. The RID canal located further uphill, on the other hand, is significantly less polluted by FC as it passes through the watershed since there are few, if any, discharges into it. The quality of the SVID and RID water entering the watershed (at Beam Road) is not significantly different. The most recent geometric mean and 90th percentile FC densities of each canal's *downstream* water were calculated respectively to be 103 cfu/100 mL/140 cfu/100 mL (SVID), and 47 cfu/100 mL/110 cfu/100 mL (RID), respectively. Only the FC geometric mean for the SVID canal does not comply with the State's Class A FC standard. As both of these canals are classified as "waters of the State", they are required to meet water quality standards.

2. FC densities throughout the Granger Drain watershed surface waters were determined to always be greatest during the irrigation season when ground water levels and surface water flows are at their highest. Since non-point pollution, rather than point source

pollution, is typically associated with precipitation events, the substantially higher FC pollution during the irrigation season leads to the assumption that non-point rather than point sources are responsible for the FC pollution and that the precipitation is actually due to irrigation.

3. FC pollution throughout the Granger Drain watershed, during 1992, was positively correlated to the acreage of rill-irrigated agriculture for the FC geometric mean densities, and correlated to the on-site acreage of dairy/feedlots for the FC 90th percentile densities. However, regression analysis for the non-irrigation season showed no such correlation.

4. During 1995, the irrigation season FC 90th percentile densities were correlated to the quantity of cows present on-site at the watershed dairies.

5. During 1998 and 2000, FC pollution throughout the Granger Drain watershed was not significantly correlated to on-site dairy parameters, but was found to be positively correlated to *row crop acres*. Thus, it is still hypothesized that FC pollution is principally transported by its adsorption to suspended sediment in overland runoff and through subsurface drainage from irrigated agriculture. Evidence includes: (1) a highly significant correlation between FC densities and TSS concentrations throughout the year; (2) the greatest FC pollution always occurs during the irrigation season; (3) an 85% decrease in TSS, from 1997-2000, was associated with a 67% decrease in FC pollution; and (4) high FC densities in both subsurface and surface drainage during the irrigation season.

6. Since 1992, FC densities in the mainstem Granger Drain have been reduced by over 90% probably due to extensive BMP implementation for controlling suspended sediment in surface runoff, as well as, improvements in on-site manure management at various dairies. However, a further reduction of 87% is still needed before the mainstem Granger Drain complies with the State two-tiered water quality Class A FC standard of a geometric mean and 90th percentile densities of 100 cfu/100 mL and 200 cfu/100 mL, respectively. That standard is projected to be met by 2010 if the same rate of FC reduction continues as has occurred in the past. The TMDL has a final target of meeting the Class A FC standard commencing with the 2012 irrigation season, and therefore has a built-in safety factor (MOS) of two years in which to implement other specialized BMPs, if the need arises.

6. An additional source of significant FC pollution in the Yakima River basin was determined to be coming from subsurface drainage systems. The results of the year-2000 USGS synoptic sampling found that the greatest FC densities, during both the irrigation and non-irrigation seasons, were collected from subsurface drainage systems. Subsurface drainage is typically described as a collection of non-point source waters that ultimately discharge into surface waters. The TMDL will require identification, mapping and monitoring of such drainage water to determine the extent of FC pollution within the Granger Drain watershed sub-basins.

7. As a side viewpoint, Table 39 details the major water quality parameters analyzed by the RSBOJC throughout the length of the mainstem Granger Drain and their respective changes from 1997 to 2000. Note: all parameters have improved, some dramatically.

Table 39: Change in 90th Percentile Values – 1997 through 2000

WaterQuality Parameter	1997 : 2000 90th Percentile Values	Amount of Change
Dissolved Oxygen (mg/L)	7.7 : 8.6*	10% ↑
Fecal Coliform Bacteria (cfu/100mL)	4,600 : 1,500	67% ↓
Nitrate + Nitrite (mg/L)	4.5 : 3.8	16% ↓
pH (standard units)	8.1 : 8.3	2% ↑
Temperature (ºC)	19.0 : 17.8	6% ↓
Total Kjeldahl Nitrogen (mg/L)	2.1 : 0.5	76% ↓
Total Phosphorus (mg/L)	1.5 : 0.4	73% ↓
Total Suspended Solids (mg/L)	946 : 142	85% ↓
Turbidity (NTU)	303 : 45	85% ↓
Flow (cfs)	68 : 61	10% ↓
Specific Conductance (µS/cm)	471 : 407	14% ↓

* 10th percentile, instead of 90th percentile.

9. A final multiple correlation analysis of all of the 1997-2000 monitoring data parameters (shown in Table 39) collected from throughout the mainstem Granger Drain showed a highly significant and moderately strong ($p < 0.0001$, $r^2 = 0.6155$, $r = 0.7845$, $n = 186$) linear correlation between FC densities and the parameters of: total phosphorus, dissolved oxygen, TKN, and specific conductivity. Of those four parameters, total phosphorus accounted for approximately 54% of the total variance (62%) found with the linear correlation. The resultant equation for the linear correlation is presented in Table 40:

Table 40: Correlation between FC and Misc. Pollutant Parameters – 1997 through 2000

$$FC = 4.57 - 0.10*W - 0.00047*X + 0.56*Y + 0.82*Z$$

where: FC = log fecal coliform density
W = dissolved oxygen concentration (mg/L) (p = 0.0005)
X = specific conductivity (µS/cm) (p = 0.0008)
Y = log TKN concentration (mg/L) (p = 0.0008)
Z = log total phosphorus concentration (mg/L) (p = 0.00001)

During the same multiple correlation analyses, it was determined that three parameters from Table 40 were found to be negatively correlated with FC pollution. Those parameters are dissolved oxygen, specific conductivity and pH. Interestingly, the USGS

(2000a) identified those same three surface water quality parameters as being the only parameters in their study found to be negatively correlated with FC densities.
The highly significant (p = 0.00001) relationship between total phosphorus and FC pollution, as observed in Table 40, above, is well-known as both pollutants are typically associated with overland runoff from agriculture. W.J. Gburek (2000) described the association of the two parameters as being extremely similar, when he stated: "In the case of P (and also pathogens), surface runoff, with its associated water-borne sediment, is the primary flow component of concern." In addition, the USGS (2000b) stated that: "Phosphorus… readily adheres to clay particles…" in a manner similar to FC bacteria, and that: "Soil erosion and transport is, therefore, the primary process by which significant amounts of particulate phosphate [and intuitively FC bacteria] travel to streams." In addition, E.D. Ongley (1996) stated that: "Measurement of phosphorus transport in North America and Europe indicate that as much as 90% of the total phosphorus flux in rivers can be in association with suspended sediment."

From the above information, it would be expected that any BMP implementation for mitigating FC pollution would also result in some amount of mitigation for phosphorus. In fact, Table 40 illustrates that from 1997-2000 the mainstem Granger Drain had a 67% reduction in 90th percentile FC densities, while at the same time having a 73% reduction in total phosphorus concentrations.

Recommendations of this Assessment/Evaluation

1. The large amount of FC reduction (87%) remaining to be completed in the mainstem Granger Drain necessitates that a *Granger Drain Fecal Coliform Bacteria TMDL* be designed, approved and implemented. This assessment/evaluation will require the complete implementation of Ecology's LYRSS TMDL and the *1998 Washington Dairy Nutrient Management Act* requirements, since their associated BMPs have had such a significant helpful effect on FC reduction (66% from 1997-2000). The full compliance with all of those requirements will reasonably assure compliance with the FC targets set forth in this assessment/evaluation.

2. FC improvement will be evaluated every two years from the date of EPA's approval of the *Granger Drain Fecal Coliform Bacteria TMDL* in order to determine progress to meet TMDL interim and final FC targets. If new sources, causes, or methods of transport are identified, new types of BMPs will need to be developed and implemented.

3. The identification and mapping of all subsurface drainage system outfalls throughout the Granger Drain watershed will be required, since these drainage waters have a tremendous potential for discharging pollution into the surface waters of the watershed. Such waters are considered as collections of non-point source waters even though they discharge through discrete pipes.

5. Non-functioning and/or malfunctioning septic tanks need in the community of Outlook need to be mitigated due to the potential of associated human health problems. The SIS

has stipulated that Ecology and Yakima County will complete sewerage of Outlook to the City of Sunnyside wastewater treatment plant by the year 2007.

6. It will be necessary to conduct extensive public outreach and technical assistance throughout the Granger Drain watershed in order to get the numerous “hobby farms” and smaller AFOs started on implementing manure management activities. There is also a large need to continue stream-bank fencing, constructing off-stream watering devices and installing buffer strips between fences and stream channels.

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APPENDIX A

APPENDIX A

1992 FC MONITORING DATA (cfu/100mL) COLLECTED BY SYCD

	Granger Drain Sub-basin						
Date	**#1&2 (MDOH)**	**#3 (NOPR)**	**#4 (YVHWD)**	**#5 (YVHEL)**	**#6 (YVHWL)**	**#7 (LCNV)**	**#8 (MHWB[3])**
3/8/1991	>1,600[1]	>1,600[1]	>1,600[1]	>1,600[1]	>1,600[1]	>1,600[1]	>1,600[1]
4/1-2/1991	>16,000[1]	2,200	2,200	2,200	2,200	5,100	2,200
5/15/1991[2]	>16,000[1]	>16,000[1]	>16,000[1]	>16,000[1]	>16,000[1]	>16,000[1]	>16,000[1]
5/29/1991[2]	22,000	22,000	22,000	16,000	9,200	22,000	16,000
6/10-11/1991[2]	22,000	51,000	<22,000[1]	92,000	<22,000[1]	22,000	<22,000[1]
6/24-25/1991[2]	160,000	>160,000[1]	>160,000[1]	160,000	22,000	22,000	160,000
7/1/1991[2]	No sample	No sample	No sample	No sample	No sample	No sample	No sample
7/8-9/1991[2]	>160,000[1]	>160,000[1]	160,000	22,000	92,000	22,000	>160,000[1]
7/22-23/1991[2]	>160,000[1]	160,000	92,000	92,000	92,000	160,000	>160,000[1]
8/5-6/1991[2]	<8,000[1]	92,000	92,000	8,000	<8,000[1]	8,000	92,000
8/19-20/1991[2]	4,400	>46,000[1]	<4,400[1]	10,200	4,400	<4,400[1]	<4,400[1]
8/27/1991[2]	46,000	18,400	10,200	10,200	10,200	10,200	4,400
9/3/1991[2]	4,400	4,400	<4,400[1]	<4,400[1]	<4,400[1]	4,400	No sample
9/10/1991[2]	4,400	10,200	<4,400[1]	<4,400[1]	<4,400[1]	10,200	<4,400[1]
9/17/1991[2]	1,920	5,290	1,260	1,920	<150[1]	<500[1]	1,260
9/23-24/1991[2]	1,058	588	1,058	384	252	252	<150[1]
10/10/1991	1,210	1,058	243	386	243	243	<150[1]
10/21/1991	440	<150[1]	<150[1]	<150[1]	<150[1]	<150[1]	<150[1]
11/19/1991	160	330	160	160	440	5,100	160
12/12/1991	3,200	220	<150[1]	220	1,200	9,100	1,600
1/14/1992	440	9,200	920	220	<150[1]	9,200	<150[1]

	Mainstem Granger Drain			
Date	**YVHLMD**	**YVLMD**	**OBMD**	**SBMD**
3/8/1991	>1,600[1]	>1,600[1]	>1,600[1]	>1,600[1]
4/1-2/1991	2,200	2,200	5,100	2,200
5/15/1991[2]	>16,000[1]	>16,000[1]	>16,000[1]	>16,000[1]
5/29/1991[2]	22,000	9,200	9,200	22,000
6/10-11/1991[2]	22,000	22,000	92,000	22,000
6/24-25/1991[2]	160,000	>160,000[1]	22,000	22,000
7/1/1991[2]	No sample	No sample	No sample	51,000
7/8-9/1991[2]	>160,000[1]	51,000	>160,000[1]	51,000
7/22-23/1991[2]	>160,000[1]	<22,000[1]	160,000	160,000
8/5-6/1991[2]	120,000	<8,000[1]	44,000	120,000
8/19-20/1991[2]	4,400	10,200	<4,400[1]	<4,400[1]

	Mainstem Granger Drain			
Date	**YVHLMD**	**YVLMD**	**OBMD**	**SBMD**
8/27/1991[2]	10,200	18,400	<4,400[1]	<4,400[1]
9/3/1991[2]	4,400	4,400	<4,400[1]	4,400
9/10/1991[2]	<4,400[1]	<4,400[1]	<4,400[1]	<4,400[1]
9/17/1991[2]	2,940	<500[1]	<500[1]	2,940
9/23-24/1991[2]	384	1,058	252	252
10/10/1991	1,840	386	<150[1]	243
10/21/1991	7,000	<150[1]	440	<150[1]
11/19/1991	160	268	160	268
12/12/1991	220	220	1,200	<150[1]
1/14/1991	2,200	510	3,200	1,600

1 For all data that is described above as < or >, this assessment/evaluation used only the pure value without consideration of the qualifier. Using this method, the resultant calculated geometric mean and 90th percentile values will be conservative in nature.
2 Date corresponds to the irrigation season.
3 Sampling site MHWB is a sub-surface drain.

APPENDIX B

APPENDIX B

1995 FC MONITORING DATA (cfu/100mL) COLLECTED BY ECOLOGY

	Sub-basin					
Date	**#1&2**	**#3**	**#4**	**#5**	**#6**	**#7**
April 10	No data	3,300	35,000	490	1,300	170
April 25	No data	11,000	790	4,900	2,400	490
May 8	No data	4,600	3,300	7,000	3,300	2,400
May 22	No data	2,800	490	1,300	3,300	7,000
June 5	No data	7,900	2,300	17,000	13,000	1,100
June 19	2,400	1,700	4,900	790	790	3,300
July 5	790	790	3,300	4,600	1,300	1,450
July 17	1,700	7,900	3,300	7,150	2,400	3,300
Aug. 1	490	4,900	1,700	3,100	4,100	1,800
Aug. 14	3,500	7,000	1,700	790	3,300	1,400
Aug. 28	1,300	7,900	3,300	3,300	7,000	1,700
Sept. 12	7,000	49,000	4,900	2,700	3,100	7,900
Sept. 25	1,300	17,000	3,300	790	790	595

	Mainstem Granger Drain				
Date	**G1 (#24)**	**G2 (#8)**	**G3 (#13)**	**G4 (#23)**	**Outlook**
April 10	700	1,300	4,600	230	No data
April 25	790	3,300	7,900	13,000	No data
May 8	1,700	35,000	10,950	2,400	No data
May 22	1,300	1,300	2,200	3,300	No data
June 5	4,900	5,150	7,900	7,000	No data
June 19	1,300	3,300	3,850	4,900	2400
July 5	790	7,900	11,000	1,700	790
July 17	490	2,400	7,900	4,900	1700
Aug. 1	2,800	1,700	4,900	1,300	490
Aug. 14	1,300	2,400	1,300	13,000	3500
Aug. 28	1,100	3,300	3,850	1,700	1300
Sept. 12	3,300	3,300	7,900	24,000	7000
Sept. 25	7,000	7,900	7,900	7,900	1300
Oct. 17	1,700	No data	No data	33,000	No data

APPENDIX C

APPENDIX C

1997, 1998, 1999 AND 2000 FC MONITORING DATA COLLECTED BY THE RSBOJC

Sub-Basin #	Sampling Location #	Sampling Date and FC Values (cfu/100 mL)									
		1997		1998		1999		2000		2001	
		Date	Value	Date	Value	Date	Value	Date	Value	Date	Value
1&2	**22.4**	-	-	4/14	1,100	1/12	380*	-	-	-	-
"	"	-	-	5/5	1,200	2/8	170*	-	-	-	-
"	"	-	-	5/19	440	3/9	270*	-	-	-	-
"	"	-	-	6/2	420	-	-	-	-	-	-
"	"	-	-	6/16	680	-	-	-	-	-	-
"	"	-	-	7/1	890	-	-	-	-	-	-
"	"	-	-	7/15	1,100	-	-	-	-	-	-
"	"	-	-	7/28	3,000	-	-	-	-	-	-
"	"	-	-	8/12	870	-	-	-	-	-	-
"	"	-	-	8/25	2,500	-	-	-	-	-	-
"	"	-	-	9/8	670	-	-	-	-	-	-
"	"	-	-	9/21	980	-	-	-	-	-	-
"	"	-	-	10/12	2,400	-	-	-	-	-	-
"	"	-	-	10/20	800	-	-	-	-	-	-
"	"	-	-	11/4	3,800*	-	-	-	-	-	-
"	"	-	-	12/2	1,100*	-	-	-	-	-	-
3	**14**	9/29	73	1/13	4*	-	-	-	-	-	-
"	"	10/14	20	2/9	3*	-	-	-	-	-	-
"	"	10/27	2	-	-	-	-	-	-	-	-
"	"	12/3	90*	-	-	-	-	-	-	-	-
"	**15**	8/5	2,300	1/13	94*	1/5	250*	1/3	<11*	-	-
"	"	9/2	1,100	2/9	130*	2/8	14*	1/31	130*	-	-
"	"	9/15	970	3/9	12*	3/2	170*	2/28	180*	-	-
"	"	9/29	320	4/14	1,600	4/12	92	4/10	57	-	-
"	"	10/14	310	5/5	1,500	4/26	120	4/24	310	-	-
"	"	10/27	7	5/19	2,500	5/10	280	5/8	200	-	-
"	"	12/3	58*	6/2	730	5/24	320	5/22	3,200	-	-
"	"	-	-	6/16	2,700	6/9	3,900	6/5	180	-	-
"	"	-	-	6/30	2,000	6/22	320	6/19	280	-	-
"	"	-	-	7/14	2,200	7/6	9,000	7/4	600	-	-
"	"	-	-	7/27	16,000	7/19	5,900	7/17	290	-	-
"	"	-	-	8/10	2,000	8/2	7,000	7/31	600	-	-
"	"	-	-	8/24	2,600	8/16	2,000	8/14	420	-	-
"	"	-	-	9/8	1,300	8/30	5,900	8/28	920	-	-
"	"	-	-	9/23	350	9/13	2,200	9/11	34	-	-
"	"	-	-	10/5	440	9/27	1,000	9/25	110	-	-
"	"	-	-	10/19	330	10/11	85	10/9	61	-	-
"	"	-	-	11/3	230*	11/1	110*	-	-	-	-
"	"	-	-	12/1	390*	11/29	15*	-	-	-	-
"	**16**	8/5	120,000	1/13	26*	-	-	-	-	-	-
"	"	9/2	5,700	2/9	25*	-	-	-	-	-	-
3 cont'd.	**16 cont'd.**	9/15	1,500	3/9	67*	-	-	-	-	-	-
"	"	9/30	1,900	-	-	-	-	-	-	-	-
"	"	10/14	37,000	-	-	-	-	-	-	-	-
"	"	10/27	23	-	-	-	-	-	-	-	-
"	"	12/3	33*	-	-	-	-	-	-	-	-

		Sampling Date and FC Values (cfu/100 mL)									
Sub-Basin #	Sampling Location #	1997		1998		1999		2000		2001	
		Date	Value	Date	Value	Date	Value	Date	Value	Date	Value
"	**17**	8/5	120,000	1/13	58*	1/5	27*	1/3	43*	-	-
"	"	9/2	4,300	2/9	42*	2/3	3.8*	1/31	110*	-	-
"	"	9/15	2,000	3/9	33*	3/2	250*	2/28	28*	-	-
"	"	9/30	1,600	4/14	120	4/12	5.7	-	-	-	-
"	"	10/14	9,700	5/5	1,400	4/26	230	-	-	-	-
"	"	10/27	7	5/19	1,300	5/10	58	-	-	-	-
"	"	12/3	23*	6/2	1,200	5/24	1,200	-	-	-	-
"	"	-	-	6/16	11,000	6/9	930	-	-	-	-
"	"	-	-	6/30	3,700	6/22	490	-	-	-	-
"	"	-	-	7/14	8,000	7/6	2,400	-	-	-	-
"	"	-	-	7/27	260	7/19	490	-	-	-	-
"	"	-	-	8/10	2,100	8/2	130	-	-	-	-
"	"	-	-	8/24	1,600	8/16	640	-	-	-	-
"	"	-	-	9/8	4,000	8/30	1,400	-	-	-	-
"	"	-	-	9/23	620	9/13	1,000	-	-	-	-
"	"	-	-	10/5	300	9/27	280	-	-	-	-
"	"	-	-	10/19	160	10/11	100	-	-	-	-
"	"	-	-	11/3	150*	11/1	150*	-	-	-	-
"	"	-	-	11/30	270*	11/29	31*	-	-	-	-
"	**18**	8/4	970	1/13	6*	-	-	-	-	-	-
"	"	9/4	700	2/9	2*	-	-	-	-	-	-
"	"	9/16	170	3/9	1*	-	-	-	-	-	-
"	"	10/1	500	-	-	-	-	-	-	-	-
"	"	10/15	25	-	-	-	-	-	-	-	-
"	"	10/28	120	-	-	-	-	-	-	-	-
"	"	12/2	12*	-	-	-	-	-	-	-	-
"	**19**	7/23	1,500	1/14	220*	-	-	-	-	-	-
"	"	8/4	1,500	2/10	230*	-	-	-	-	-	-
"	"	8/19	3,000	3/9	510*	-	-	-	-	-	-
"	"	9/4	1,900	4/14	770	-	-	-	-	-	-
"	"	9/16	900	5/5	1,000	-	-	-	-	-	-
"	"	10/1	5,600	5/19	680	-	-	-	-	-	-
"	"	10/15	310	6/2	320	-	-	-	-	-	-
"	"	10/28	2,700	-	-	-	-	-	-	-	-
"	"	12/2	260*	-	-	-	-	-	-	-	-
"	**19.1**	-	-	6/23	570	1/12	85*	1/12	28*	-	-
"	"	-	-	7/7	580	2/3	20*	2/3	5.2*	-	-
"	"	-	-	7/21	1,500	3/9	39*	3/2	3.8*	-	-
"	"	-	-	8/5	1,500	4/12	69	4/10	37	-	-
"	"	-	-	8/18	2,500	4/26	63	4/24	61	-	-
"	"	-	-	8/26	1,600	5/10	420	5/8	220	-	-
"	"	-	-	9/2	2,000	5/26	1,200	5/22	840	-	-
"	"	-	-	9/15	4,000	6/7	440	6/5	210	-	-
"	"	-	-	9/30	320	6/23	730	6/19	560	-	-
3 cont'd.	**19.1 cont'd.**	-	-	10/12	720	7/7	830	7/4	580	-	-
"	"	-	-	11/3	380*	7/19	3,400	7/17	490	-	-
"	"	-	-	12/2	160*	8/2	380	7/31	1,600	-	-
"	"	-	-	-	-	8/17	2,200	8/14	1,200	-	-
"	"	-	-	-	-	8/31	1,100	8/28	2,300	-	-
"	"	-	-	-	-	9/14	310	9/11	430	-	-
"	"	-	-	-	-	9/28	450	9/25	280	-	-
"	"	-	-	-	-	10/12	3,300	10/9	170	-	-
"	"	-	-	-	-	11/1	900*	10/31	100*	-	-

		Sampling Date and FC Values (cfu/100 mL)									
Sub-Basin #	**Sampling Location #**	**1997**		**1998**		**1999**		**2000**		**2001**	
		Date	**Value**	**Date**	**Value**	**Date**	**Value**	**Date**	**Value**	**Date**	**Value**
"	"	-	-	-	-	11/30	99*	-	-	-	-
"	**20**	7/23	2,700	1/14	220*	-	-	-	-	-	-
"	"	8/4	220	2/10	140*	-	-	-	-	-	-
"	"	8/19	5,700	-	-	-	-	-	-	-	-
"	"	9/4	1,900	-	-	-	-	-	-	-	-
"	"	9/16	600	-	-	-	-	-	-	-	-
"	"	10/1	4,400	-	-	-	-	-	-	-	-
"	"	10/15	120	-	-	-	-	-	-	-	-
"	"	10/28	370	-	-	-	-	-	-	-	-
"	"	12/2	230*	-	-	-	-	-	-	-	-
"	**20.1**	-	-	7/14	1,700	1/12	50*	-	-	-	-
"	"	-	-	7/27	1,600	2/3	1,400*	-	-	-	-
"	"	-	-	8/10	5,000	3/9	34*	-	-	-	-
"	"	-	-	8/24	3,700	4/26	290	-	-	-	-
"	"	-	-	9/2	2,300	5/10	290	-	-	-	-
"	"	-	-	9/15	3,600	5/26	6,000	-	-	-	-
"	"	-	-	9/30	1,900	6/7	610	-	-	-	-
"	"	-	-	10/12	820	6/23	27,000	-	-	-	-
"	"	-	-	11/3	620*	7/6	830	-	-	-	-
"	"	-	-	12/2	2,000*	7/19	1,100	-	-	-	-
"	"	-	-	-	-	8/2	2,000	-	-	-	-
"	"	-	-	-	-	8/17	4,600	-	-	-	-
"	"	-	-	-	-	8/31	38,000	-	-	-	-
"	"	-	-	-	-	9/14	650	-	-	-	-
"	"	-	-	-	-	9/28	510	-	-	-	-
"	"	-	-	-	-	10/12	280	-	-	-	-
"	"	-	-	-	-	11/1	32*	-	-	-	-
"	"	-	-	-	-	11/30	37*	-	-	-	-
"	**21**	7/23	4,400	1/14	130*	-	-	-	-	-	-
"	"	8/4	930	2/10	120*	-	-	-	-	-	-
"	"	8/19	9,000	3/10	1,400*	-	-	-	-	-	-
"	"	9/4	2,000	-	-	-	-	-	-	-	-
"	"	9/16	970	-	-	-	-	-	-	-	-
"	"	10/1	3,500	-	-	-	-	-	-	-	-
"	"	10/15	310	-	-	-	-	-	-	-	-
"	"	10/28	470	-	-	-	-	-	-	-	-
"	"	12/2	210*	-	-	-	-	-	-	-	-
"	**22**	7/23	350	1/14	370*	-	-	-	-	-	-
"	"	8/4	3,000	2/10	2,900*	-	-	-	-	-	-
"	"	8/19	7,300	3/10	620*	-	-	-	-	-	-
3 cont'd.	**22 cont'd.**	9/4	5,400	-	-	-	-	-	-	-	-
"	"	9/16	970	-	-	-	-	-	-	-	-
"	"	10/1	4,500	-	-	-	-	-	-	-	-
"	"	10/15	7,700	-	-	-	-	-	-	-	-
"	"	10/28	120	-	-	-	-	-	-	-	-
"	"	12/2	670*	-	-	-	-	-	-	-	-
"	**22.2**	-	-	4/14	420	1/12	410*	1/4	24*	-	-
"	"	-	-	5/5	4,200	2/8	110*	2/1	350*	-	-
"	"	-	-	5/19	1,700	3/9	230*	2/29	150*	-	-
"	"	-	-	6/2	730	4/20	1,900	-	-	-	-
"	"	-	-	6/16	2,900	5/4	3,700	-	-	-	-
"	"	-	-	7/1	2,400	5/17	3,300	-	-	-	-
"	"	-	-	7/15	3,200	6/2	1,300	-	-	-	-

		Sampling Date and FC Values (cfu/100 mL)									
Sub-Basin #	Sampling Location #	1997		1998		1999		2000		2001	
		Date	Value	Date	Value	Date	Value	Date	Value	Date	Value
"	"	-	-	7/28	2,300	6/15	770	-	-	-	-
"	"	-	-	8/12	3,400	6/30	1,200	-	-	-	-
"	"	-	-	8/26	8,300	7/14	1,400	-	-	-	-
"	"	-	-	9/8	3,400	7/26	770	-	-	-	-
"	"	-	-	9/22	12,000	8/11	2,700	-	-	-	-
"	"	-	-	10/12	460	8/25	3,100	-	-	-	-
"	"	-	-	10/20	3,700	9/14	900	-	-	-	-
"	"	-	-	11/2	2,600*	9/21	830	-	-	-	-
"	"	-	-	12/2	3,800*	10/6	620	-	-	-	-
"	"	-	-	-	-	10/19	190	-	-	-	-
"	"	-	-	-	-	11/1	37*	-	-	-	-
"	"	-	-	-	-	11/30	180*	-	-	-	-
1&2+3	**23**	7/23	1,100	1/14	820*	1/12	210*	1/4	46*	1/8	420*
"	"	8/5	3,600	2/10	2,400*	2/8	74*	2/2	280*	2/5	180*
"	"	8/19	190	3/10	1,000*	3/9	66*	2/29	58*	3/12	14*
"	"	9/4	15,000	4/14	320	4/21	1,400	4/10	77	-	-
"	"	9/16	4,500	5/5	750	5/5	3,300	4/24	37	-	-
"	"	10/1	2,000	5/19	200	5/17	1,200	5/8	150	-	-
"	"	10/15	2,100	6/2	500	6/1	1,400	5/22	580	-	-
"	"	10/28	580	6/17	2,200	6/15	560	6/5	340	-	-
"	"	12/2	3,500*	7/1	1,500	6/30	2,300	6/19	370	-	-
"	"	-	-	7/15	1,800	7/14	9,700	7/4	1,900	-	-
"	"	-	-	7/28	2,500	7/26	1,700	7/17	260	-	-
"	"	-	-	8/12	1,600	8/11	1,500	7/31	330	-	-
"	"	-	-	9/2	1,200	8/25	3,200	8/14	430	-	-
"	"	-	-	9/9	870	9/15	770	8/28	1,200	-	-
"	"	-	-	9/21	830	9/22	1,300	9/11	170	-	-
"	"	-	-	10/7	1,800	10/6	160	9/25	360	-	-
"	"	-	-	10/20	520	10/20	420	10/9	200	-	-
"	"	-	-	11/2	690*	11/3	91*	10/30	170*	-	-
"	"	-	-	12/2	590*	11/30	110*	12/4	100*	-	-
4	**12**	8/12	1,700	1/5	1,200*	-	-	-	-	-	-
"	"	8/26	2,400	2/3	2,300*	-	-	-	-	-	-
"	"	9/8	2,100	3/10	360*	-	-	-	-	-	-
"	"	9/24	2,900	-	-	-	-	-	-	-	-
"	"	10/7	5,600	-	-	-	-	-	-	-	-
4 cont'd	**12 cont'd.**	10/20	18,000	-	-	-	-	-	-	-	-
"	"	11/25	1,200*	-	-	-	-	-	-	-	-
"	**12.1**	-	-	4/15	440	1/6	220*	1/3	640*	1/8	150*
"	"	-	-	5/6	1,700	2/2	2,800*	2/1	50*	2/5	40*
"	"	-	-	5/20	830	3/3	1,800*	2/29	11*	3/12	96*
"	"	-	-	6/1	2,000	4/21	220	4/10	1,400	-	-
"	"	-	-	6/17	1,500	5/5	1,100	4/22	360	-	-
"	"	-	-	7/1	3,700	5/17	700	5/8	150	-	-
"	"	-	-	7/13	5,300	6/1	5,000	5/22	1,100	-	-
"	"	-	-	7/28	14,000	6/30	3,700	6/5	1,600	-	-
"	"	-	-	8/12	2,200	7/14	1,700	6/19	1,000	-	-
"	"	-	-	8/25	3,100	7/28	3,100	7/4	500	-	-
"	"	-	-	9/9	1,400	8/11	6,200	7/17	3,900	-	-
"	"	-	-	9/21	2,400	8/25	2,900	7/31	2,700	-	-
"	"	-	-	10/7	370	9/15	1,600	8/14	1,400	-	-
"	"	-	-	10/20	230	9/22	1,000	8/28	1,400	-	-
"	"	-	-	11/2	150*	10/6	360	9/11	1,000	-	-

		Sampling Date and FC Values (cfu/100 mL)									
Sub-Basin #	Sampling Location #	1997		1998		1999		2000		2001	
		Date	Value	Date	Value	Date	Value	Date	Value	Date	Value
"	"	-	-	11/30	1,700*	10/20	240	9/25	430	-	-
"	"	-	-	-	-	11/3	340*	10/9	1,100	-	-
"	"	-	-	-	-	11/30	280*	10/30	300*	-	-
"	"	-	-	-	-	-	-	12/4	410*	-	-
5	**9**	8/12	3,100	5/6	2,300	4/26	9,000	-	-	-	-
"	"	8/26	5,500	5/20	16,000	5/10	13,000	-	-	-	-
"	"	9/8	360	6/1	5,100	5/24	5,000	-	-	-	-
"	"	-	-	6/15	1,600	6/9	2,300	-	-	-	-
"	"	-	-	6/30	1,700	6/21	5,500	-	-	-	-
"	"	-	-	7/13	2,500	7/20	140,000	-	-	-	-
"	"	-	-	7/27	1,900	8/2	71,000	-	-	-	-
"	"	-	-	8/10	930	8/16	2,900	-	-	-	-
"	"	-	-	8/24	6,700	8/30	11,000	-	-	-	-
"	"	-	-	9/8	3,900	9/13	7,000	-	-	-	-
"	"	-	-	9/23	10,000	9/27	110	-	-	-	-
"	"	-	-	10/5	28,000	10/11	1,100	-	-	-	-
"	**10**	8/12	2,300	-	-	-	-	-	-	-	-
"	"	8/26	2,300	-	-	-	-	-	-	-	-
"	"	9/8	450	-	-	-	-	-	-	-	-
"	"	9/24	2,100	-	-	-	-	-	-	-	-
"	"	10/20	17	-	-	-	-	-	-	-	-
"	**11**	8/12	1,200	1/5	31*	-	-	-	-	-	-
"	"	8/26	2,000	2/2	3*	-	-	-	-	-	-
"	"	9/8	240	3/10	1*	-	-	-	-	-	-
"	"	9/24	8,700	-	-	-	-	-	-	-	-
"	"	10/7	100	-	-	-	-	-	-	-	-
"	"	10/20	41	-	-	-	-	-	-	-	-
"	"	11/25	18*	-	-	-	-	-	-	-	-
"	**11.5**	-	-	4/15	600	1/6	30*	1/4	2.8*	1/8	4.3*
"	"	-	-	5/6	2,100	2/2	23*	2/1	2.0*	2/5	9.2*
"	"	-	-	5/20	2,400	3/3	27*	3/1	7.7*	3/12	3.2*
"	"	-	-	6/1	1,900	4/21	1,500	4/10	150	-	-
5 cont'd.	**11.5 cont'd.**	-	-	6/17	900	5/5	1,100	4/24	430	-	-
"	"	-	-	6/30	1,300	5/17	8,300	5/8	2,500	-	-
"	"	-	-	7/13	1,400	6/1	5,200	5/22	2,600	-	-
"	"	-	-	7/29	2,200	6/30	1,700	6/6	3,200	-	-
"	"	-	-	8/11	2,100	7/14	1,600	6/19	1,400	-	-
"	"	-	-	8/25	2,400	7/28	1,700	7/4	720	-	-
"	"	-	-	9/9	6,700	8/11	3,300	7/17	930	-	-
"	"	-	-	9/22	930	8/25	3,400	7/31	1,500	-	-
"	"	-	-	10/12	780	9/15	2,200	8/14	1,900	-	-
"	"	-	-	10/21	170	9/22	1,600	8/28	1,300	-	-
"	"	-	-	11/4	33*	10/6	390	9/11	640	-	-
"	"	-	-	11/30	63*	10/20	570	9/25	970	-	-
"	"	-	-	-	-	11/3	14*	10/9	2,300	-	-
"	"	-	-	-	-	12/1	62*	10/30	34*	-	-
"	"	-	-	-	-	-	-	12/4	8.6*	-	-
1&2+3+ 4+5	**13**	8/11	1,600	1/7	470*	-	-	-	-	-	-
"	"	8/27	2,100	2/3	5,300*	-	-	-	-	-	-
"	"	9/10	1,100	3/18	120*	-	-	-	-	-	-
"	"	9/24	1,300	-	-	-	-	-	-	-	-
"	"	10/7	3,300	-	-	-	-	-	-	-	-

Sub-Basin #	Sampling Location #	Sampling Date and FC Values (cfu/100 mL)									
		1997		1998		1999		2000		2001	
		Date	Value	Date	Value	Date	Value	Date	Value	Date	Value
"	"	10/21	670	-	-	-	-	-	-	-	-
"	"	11/25	420*	-	-	-	-	-	-	-	-
6	**6**	8/11	26,000	1/5	15*	-	-	-	-	-	-
"	"	8/27	23,000	2/2	400*	-	-	-	-	-	-
"	"	9/10	24,000	3/18	32*	-	-	-	-	-	-
"	"	9/22	3,200	-	-	-	-	-	-	-	-
"	"	10/7	340	-	-	-	-	-	-	-	-
"	"	10/21	110	-	-	-	-	-	-	-	-
"	"	11/24	350*	-	-	-	-	-	-	-	-
"	**7**	8/11	3,700	1/5	590*	1/6	430*	1/3	520*	1/8	370*
"	"	8/27	1,800	2/2	480*	2/2	360*	2/1	400*	2/5	4,300*
"	"	9/10	4,800	3/18	5,800*	3/2	440*	3/1	970*	3/12	16*
"	"	9/22	800	4/15	2,100	4/21	230	4/10	2,500	-	-
"	"	10/7	800	5/6	4,500	5/5	400	4/24	4,800	-	-
"	"	10/21	550	5/20	6,200	5/17	440	5/8	300	-	-
"	"	11/24	1,800*	6/1	1,800	6/1	1,200	5/22	1,100	-	-
"	"	-	-	6/15	2,200	6/30	1,900	6/6	530	-	-
"	"	-	-	6/30	1,600	7/14	2,900	6/19	810	-	-
"	"	-	-	7/13	44,000	7/28	5,600	7/4	2,200	-	-
"	"	-	-	7/28	3,200	8/11	2,200	7/17	670	-	-
"	"	-	-	8/11	1,400	8/25	3,800	7/31	3,600	-	-
"	"	-	-	8/25	420	9/15	1,000	8/14	780	-	-
"	"	-	-	9/9	1,200	9/22	890	8/28	2,400	-	-
"	"	-	-	9/22	93	10/6	140	9/11	310	-	-
"	"	-	-	10/5	1,700	10/20	700	9/25	820	-	-
"	"	-	-	10/19	83	11/3	1,200*	10/9	730	-	-
"	"	-	-	11/3	300*	12/1	6,000*	10/31	260*	-	-
"	"	-	-	11/30	120*	-	-	12/4	520*	-	-
1&2+3+ 4+5+6	**7.5**	-	-	-	-	-	-	4/11	720	1/8	91*
"	"	-	-	-	-	-	-	4/25	5,200	2/6	69*
"	"	-	-	-	-	-	-	5/9	1,700	3/12	69*
"	"	-	-	-	-	-	-	5/23	1,100	-	-
"	"	-	-	-	-	-	-	6/6	1,200	-	-
"	"	-	-	-	-	-	-	6/20	690	-	-
"	"	-	-	-	-	-	-	7/5	1,600	-	-
"	"	-	-	-	-	-	-	7/18	720	-	-
"	"	-	-	-	-	-	-	8/1	1,000	-	-
"	"	-	-	-	-	-	-	8/15	560	-	-
"	"	-	-	-	-	-	-	8/29	720	-	-
"	"	-	-	-	-	-	-	9/12	670	-	-
"	"	-	-	-	-	-	-	9/26	410	-	-
"	"	-	-	-	-	-	-	10/10	390	-	-
"	"	-	-	-	-	-	-	10/31	360*	-	-
"	"	-	-	-	-	-	-	12/4	330*	-	-
"	**8**	8/13	4,800	1/7	920*	-	-	-	-	-	-
"	"	8/27	2,600	2/3	5,700*	-	-	-	-	-	-
"	"	9/9	700	3/18	34*	-	-	-	-	-	-
"	"	9/23	1,000	-	-	-	-	-	-	-	-
"	"	10/6	1,200	-	-	-	-	-	-	-	-
"	"	11/24	880*	-	-	-	-	-	-	-	-
7	**1**	9/9	510,000	1/7	1,100*	1/5	830*	1/3	120*	-	-
"	"	-	-	2/4	480*	2/2	660*	1/31	8.6*	-	-

		Sampling Date and FC Values (cfu/100 mL)									
Sub-Basin #	**Sampling Location #**	**1997**		**1998**		**1999**		**2000**		**2001**	
		Date	**Value**	**Date**	**Value**	**Date**	**Value**	**Date**	**Value**	**Date**	**Value**
"	"	-	-	3/16	67*	3/2	280*	2/28	1,300*	-	-
"	"	-	-	4/13	470	4/13	340	-	-	-	-
"	"	-	-	5/4	1,000	4/27	1,300	-	-	-	-
"	"	-	-	5/18	660	5/10	780	-	-	-	-
"	"	-	-	6/3	1,200	5/24	1,600	-	-	-	-
"	"	-	-	6/15	2,200	6/21	15,000	-	-	-	-
"	"	-	-	6/29	130,000	8/16	2,500	-	-	-	-
"	"	-	-	7/14	2,000	8/30	3,500	-	-	-	-
"	"	-	-	8/24	6,700	10/11	300	-	-	-	-
"	"	-	-	9/8	1,200	11/1	500*	-	-	-	-
"	"	-	-	9/23	2,800	11/29	88*	-	-	-	-
"	"	-	-	10/5	1,200	-	-	-	-	-	-
"	"	-	-	10/19	870	-	-	-	-	-	-
"	"	-	-	11/2	1,000*	-	-	-	-	-	-
"	"	-	-	12/1	830*	-	-	-	-	-	-
"	**2**	8/13	1,200	1/7	220*	-	-	-	-	-	-
"	"	8/27	2,300	2/4	220*	-	-	-	-	-	-
"	"	9/9	67,000	3/16	160*	-	-	-	-	-	-
"	"	9/23	220	-	-	-	-	-	-	-	-
"	"	10/6	460	-	-	-	-	-	-	-	-
"	"	10/22	170	-	-	-	-	-	-	-	-
"	"	11/24	59*	-	-	-	-	-	-	-	-
"	**3**	8/13	1,200	1/7	50*	1/6	330*	4/11	14	1/8	67*
"	"	8/27	1,400	2/4	230*	2/2	140*	4/25	800	2/5	11*
7 cont'd.	**3 cont'd.**	9/9	33,000	3/16	21*	3/3	110*	5/9	180	3/12	12*
"	"	9/23	720	4/13	50	4/21	2,700	5/23	310	-	-
"	"	10/6	320	5/4	820	5/5	2,000	6/6	600	-	-
"	"	10/22	140	5/18	520	5/18	870	6/20	400	-	-
"	"	11/24	47*	6/3	390	6/1	3,100	7/5	240	-	-
"	"	-	-	6/15	630	6/30	800	7/18	290	-	-
"	"	-	-	6/29	240	7/14	5,000	8/1	170	-	-
"	"	-	-	7/15	700	7/28	1,800	8/15	370	-	-
"	"	-	-	7/29	1,500	8/11	730	8/29	210	-	-
"	"	-	-	8/12	720	8/25	660	9/12	110	-	-
"	"	-	-	8/26	460	9/15	400	9/26	380	-	-
"	"	-	-	9/9	11,000	9/22	1,000	10/10	180	-	-
"	"	-	-	9/23	370	10/6	220	10/31	58*	-	-
"	"	-	-	10/7	460	10/20	96	12/4	92*	-	-
"	"	-	-	10/21	38	11/1	540*	-	-	-	-
"	"	-	-	11/4	180*	11/29	230*	-	-	-	-
"	"	-	-	12/1	8,200*	-	-	-	-	-	-
"	**4**	8/11	1,700	4/13	200	4/13	75	-	-	-	-
"	"	8/26	2,700	5/4	1,800	4/27	2,500	-	-	-	-
"	"	9/8	2,400	5/18	380	5/10	930	-	-	-	-
"	"	9/22	260	6/3	690	5/24	10,000	-	-	-	-
"	"	-	-	6/15	2,000	6/9	1,600	-	-	-	-
"	"	-	-	6/29	340	6/21	1,100	-	-	-	-
"	"	-	-	7/14	510	7/6	1,500	-	-	-	-
"	"	-	-	7/27	1,500	7/20	350	-	-	-	-
"	"			8/10	1,500	8/2	950	-	-	-	-
"	"			8/24	1,200	8/16	240	-	-	-	-
"	"	-	-	9/2	2,900	8/30	1,200	-	-	-	-
"	"	-	-	9/23	2,200	9/13	5,500	-	-	-	-

Sub-Basin #	Sampling Location #	1997 Date	1997 Value	1998 Date	1998 Value	1999 Date	1999 Value	2000 Date	2000 Value	2001 Date	2001 Value
		Sampling Date and FC Values (cfu/100 mL)									
“	“	-	-	10/5	870	9/27	19,000	-	-	-	-
“	“	-	-	-	-	10/11	280	-	-	-	-
“	“	-	-	-	-	11/1	540*	-	-	-	-
“	“	-	-	-	-	11/29	230*	-	-	-	-
“	**5**	8/11	1,800	9/23	160	-	-	-	-	-	-
“	“	8/26	2,100	-	-	-	-	-	-	-	-
“	“	9/8	2,100	-	-	-	-	-	-	-	-
“	“	9/22	330	-	-	-	-	-	-	-	-
1&2+3+4+5+6+7	**24**	8/6	1,400	1/12	1,800*	1/13	300*	1/4	130*	1/9	260*
“	“	8/20	2,200	2/11	1,100*	2/10	190*	2/2	240*	2/6	150*
“	“	9/3	4,000	3/11	430*	3/10	160*	2/29	100*	3/13	46*
“	“	9/17	1,500	4/13	430	4/21	950	4/11	3,200	-	-
“	“	9/23	770	5/4	1,200	5/5	1,300	4/25	880	-	-
“	“	9/30	1,000	5/18	830	5/18	1,000	5/9	390	-	-
“	“	10/6	530	6/2	590	6/1	1,900	5/23	1,100	-	-
“	“	10/16	560	6/15	2,400	6/30	2,200	6/6	870	-	-
“	“	10/29	3,200	6/29	1,300	7/14	3,400	6/20	440	-	-
“	“	12/1	1,100*	7/15	1,200	7/28	2,200	7/5	1,200	-	-
“	“	-	-	7/29	1,100	8/11	1,800	7/18	680	-	-
1&2+3+4+5+6+7 cont’d.	**24 cont’d.**	-	-	8/11	1,700	8/25	1,500	8/1	840	-	-
“	“	-	-	8/26	1,300	9/15	680	8/15	570	-	-
“	“	-	-	9/9	2,100	9/22	1,300	8/29	690	-	-
“	“	-	-	9/22	730	10/6	400	9/12	570	-	-
“	“	-	-	10/7	880	10/20	280	9/26	360	-	-
“	“	-	-	10/21	240	11/2	110*	10/10	740	-	-
“	“	-	-	11/4	280*	11/3	530*	10/31	260*	-	-
“	“	-	-	12/1	2,000*	12/1	130*	12/6	320*	-	-

* Data collected during the non-irrigation season (November – March)

APPENDIX D

APPENDIX D

1999 USGS SYNOPTIC SAMPLING FROM YAKIMA RIVER BASIN

		FC (cfu/100 mL)			*E. coli* (cfu/100 mL)		
Location	**Date**	**Left Bank**	**Center**	**Right Bank**	**Left Bank**	**Center**	**Right Bank**
Yakima River at Cle Elum	8/2	3	3	3	3	-	3
Wilson Creek	8/2	-	650	-	-	650	-
Cherry Creek	8/2	-	260	-	-	250	-
Yakima River at Umtanum	8/2	66	57	55	63	57	55
Umtanum Creek	8/2	-	92	-	-	92	-
Naches River	8/3	39	37	16	39	37	15
Pacific P&L	8/3	-	17	-	-	17	-
Ahtanum Creek at Union Gap	8/3	-	370	-	-	370	-
Yakima River above Ahtanum Creek	8/3	60	51	53	60	51	53
Wide Hollow Creek	8/3	-	600	-	-	600	-
Moxee Drain	8/3	-	620	-	-	620	-
Satus Creek at Wilson Charlie	8/3	-	3	-	-	3	-
East Toppenish Drive	8/3	-	840	-	-	840	-
Sub-Drain #35	8/3	-	350	-	-	350	-
Granger Drain	8/3	-	1,800	-	-	1,800	-
Moxee Drain	8/3	-	2,900	-	-	2,700	-
Marion Drain	8/4	-	430	-	-	430	-
Satus Creek below Dry Creek	8/4	-	100	-	-	100	-
Granger Drain	8/4	-	2,100	-	-	2,000	-
Toppenish Creek	8/4	-	450	-	-	450	-
Yakima River at River Mile 72	8/4	100	100	150	100	84	150
South Drain #1	8/4	-	720	-	-	720	-
Satus Creek at Mouth	8/4	-	140	-	-	140	-
Sulphur Creek	8/4	-	1,400	-	-	1,400	-
Spring Creek	8/5	-	580	-	-	560	-
Snipes Creek	8/5	-	210	-	-	210	-
Yakima River at Kiona*	8/5	166	127	102	37	18	28

* Samples analyzed by Coffee Laboratories in Portland, Oregon

APPENDIX E

APPENDIX E

2000 USGS/ECOLOGY SYNOPTIC SAMPLING FROM YAKIMA RIVER BASIN

Location of Sampling Site	Sampling Site ID#	Date	FC (cfu/100 mL)
Drain near Postma Road	2	7/11	600
"	2	7/11	670
"	2	7/12	1,500
"	2	7/13	8
"	2	7/18	110
"	2	10/30	23
	2	10/31	21
"	2	11/1	11
"	2	11/1	53
319 Test Site Drain near Walters Road *	12	7/18	96
"	12	10/30	23
Drain at Draper Road	14	7/14	170
Drain at Borquin Road	26	7/11	2,700
"	26	7/11	3,900
"	26	7/12	1,600
"	26	7/14	1,400
Drain at Lombard Loop	27	7/12	380
Drain at Hiland Drive	28	7/10	610
"	28	7/10	400
"	28	10/30	31
JD-34.2 at Woodin Road	29	7/13	700
"	29	11/1	26
Drain at Sorenson Road	47	7/11	1,000
"	47	11/2	8
Drain at Hamilton Road	48	7/11	43
"	48	11/2	4
Badger Creek at Silica Road	49	7/12	8,100
"	49	11/2	4,300
DR-2 near Outlook Fire Station (Manhole) *	50	7/19	1,100
"	50	11/1	6
Drain at Colwash Road	51	7/13	260
Drain at Evans Road	53	7/13	31
JD-51.4 at Lemley Road (Manhole) *	54	7/19	460,000
"	54	11/2	1
Spring Creek at Evans Road	55	7/19	170
"	55	10/31	3
Badger Creek upstream of Whipple Wasteway	62	7/11	210
DR-19 at Factory Road (Manhole) *	63	7/11	17,000
"	63	7/11	3,600
"	63	7/12	3,700
"	63	7/12	140 **
"	63	7/18	860

Location of Sampling Site	Sampling Site ID#	Date	FC (cfu/100 mL)
“	63	10/30	12,000
“	63	10/31	340
“	63	11/1	100
“	63	11/1	50
Umtanum Creek	66	7/17	14
“	66	11/1	21
Granger Drain at Granger	67	7/18	910
“	67	11/2	130
Moxee Drain at Birchfield Road	69	7/20	580
“	69	10/31	120
Satus Creek downstream of Dry Creek	74	7/13	29
“	74	10/31	74
Drain at Griffin Road	83	7/19	4,100
Park Creek at Park Creek Road	84	7/12	2,700
“	84	11/2	35
Drain at Park Creek Road	85	7/12	6,300
“	85	11/2	93
JD-51.4 at Yakima River	87	7/10	210
“	87	10/30	9
“	87	11/1	66
“	87	11/2	29
JD-52.8 at Wamba Road	88	7/10	2,000
“	88	10/30	51
Drain at VanBelle Road	92	7/18	3,500
“	92	10/30	270
North Drain at Satus Longhouse Road	93	7/11	140
“	93	7/11	84
“	93	7/12	150
“	93	7/12	236 **
“	93	7/18	120
“	93	10/30	40
“	93	10/30	20
“	93	11/1	50
“	93	11/2	21
Park Creek at South Ferguson Road	95	7/11	290
“	95	11/2	29
Johnson Drain at South Fergusen Road	96	7/11	3
Moxee Drain at Beane Road	97	7/20	960
“	97	10/31	23
Ahtanum Creek downstream of Bachelor Creek	99	7/13	80
“	99	10/31	53
DR-2 at Yakima Valley Highway	100	7/17	5,800
“	100	10/30	570
JD-32.0 upstream of DR-2	101	7/17	540
“	101	10/30	170
South Drain near Satus	102	7/13	250
“	102	11/1	41
JD-37.9 at East Edison Road	103	7/11	290
“	103	11/2	170
JD-43.9 at Mabton-Sunnyside Road	104	7/11	1,800

Location of Sampling Site	Sampling Site ID#	Date	FC (cfu/100 mL)
“	104	11/2	640
Spring Creek at Hanks Road	105	7/19	60
Snipes Creek at McCreadie Road	106	7/20	240
“	106	10/31	9
Ahtanum Creek at 62nd Avenue	107	7/13	930
“	107	10/31	1,600
KRD Canal at Wipple Wasteway	108	7/11	49
Roza Canal at Beam Road	109	7/17	34
Roza Canal at Ray Road	110	7/19	27
SVID Canal at North Outlook Road	111.1	7/18	88
Grandview Pump Lateral	112	7/19	120
West Lateral at Satus Pump Station #2	113	7/12	270
Cascade Canal at Thrall Road	114	7/11	500
Selah-Moxee Canal at Duffield Road	115	7/19	40
SVID Canal at East Edison Road	116	7/18	120
Yakima-Tieton Canal at Occidental Rd.	119	7/13	310
Union Gap Canal at Blue Goose Road	120	7/10	96
Yakima River at Kiona – Right Bank	K10NARB	7/19	24
Yakima River at Kiona – Centroid	K10NAC	7/19	29
Yakima River at Kiona – Left Bank	K10NALB	7/19	32

* Subsurface Drainage sampling sites.
** Analyses conducted at the City of Yakima POTW.

APPENDIX F

APPENDIX F

2000 USGS/ECOLOGY SYNOPTIC SAMPLING FROM YAKIMA RIVER BASIN

Site ID#	General Locale	FC Density (cfu/100 mL)
47	Kittitas	1,000
“	Kittitas	8*
48	Kittitas	43
“	Kittitas	4*
49	Kittitas	8,100
“	Kittitas	4,300*
62	Kittitas	210
84	Kittitas	2,700
“	Kittitas	35*
85	Kittitas	6,300
“	Kittitas	93*
95	Kittitas	290
“	Kittitas	29*
96	Kittitas	3
108	Kittitas	49
114	Kittitas	500
66	Umtanum	14
“	Umtanum	21*
14	Ahtanum - Wide Hollow	170
99	Ahtanum - Wide Hollow	80
“	Ahtanum - Wide Hollow	53*
107	Ahtanum - Wide Hollow	930
“	Ahtanum - Wide Hollow	1,600*
119	Ahtanum - Wide Hollow	310
2	Moxee	600
“	Moxee	670
“	Moxee	1,500
“	Moxee	8
“	Moxee	23*
“	Moxee	21*
“	Moxee	11*
“	Moxee	53*
“	Moxee	110*
12	Moxee	96
“	Moxee	23*
69	Moxee	580
69 cont’d.	Moxee	120*
97	Moxee	795

Site ID#	General Locale	FC Density (cfu/100 mL)
“	Moxee	23*
109	Moxee	34
115	Moxee	40
26	Buena - Zillah	2,700
“	Buena - Zillah	3,900
“	Buena - Zillah	1,600
“	Buena - Zillah	1,400
27	Buena - Zillah	380
28	Buena - Zillah	610
“	Buena - Zillah	400
“	Buena - Zillah	31*
120	Buena - Zillah	96
50	Granger	1,100
“	Granger	6*
67	Granger	910
“	Granger	130*
92	Granger	3,500
“	Granger	270*
100	Granger	5,800
“	Granger	570*
101	Granger	540
“	Granger	170*
111.1	Granger	88
51	Satus	260
74	Satus	29
“	Satus	21*
93	Satus	140
“	Satus	84
“	Satus	150
“	Satus	236
“	Satus	120
“	Satus	21*
“	Satus	40*
“	Satus	20*
“	Satus	50*
102	Satus	250
“	Satus	41*
113	Satus	270
29	Sulphur Creek	700
“	Sulphur Creek	26*
“	Sulphur Creek	170*
63	Sulphur Creek	17,000
“	Sulphur Creek	3,600
“	Sulphur Creek	3,700
“	Sulphur Creek	140
“	Sulphur Creek	860
“	Sulphur Creek	100*

Site ID#	General Locale	FC Density (cfu/100 mL)
“	Sulphur Creek	50*
“	Sulphur Creek	12,000*
“	Sulphur Creek	340*
103	Sulphur Creek	290
104	Sulphur Creek	1,800
“	Sulphur Creek	640*
110	Sulphur Creek	27
116	Sulphur Creek	120
53	Spring - Snipes	31
54	Spring - Snipes	460,000
“	Spring - Snipes	1*
55	Spring - Snipes	170
“	Spring - Snipes	3*
83	Spring - Snipes	4,100
87	Spring - Snipes	210
“	Spring - Snipes	29*
“	Spring - Snipes	9*
“	Spring - Snipes	66*
88	Spring - Snipes	2,000
“	Spring - Snipes	51*
105	Spring - Snipes	60
106	Spring - Snipes	240
“	Spring - Snipes	9*
112	Spring - Snipes	120
K10NA	Kiona	24
“	Kiona	29
“	Kiona	32

* Non-irrigation season sample.